COMPARATIVE EVALUATION OF THE SHEAR BOND STRENGTH OF CHAIRSIDE SOFT LINERS TO DENTURE BASE RESIN – AN IN VITRO STUDY

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BRANCH I

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CERTIFICATE

This is to certify that the dissertation titled **"COMPARATIVE EVALUATION OF THE SHEAR BOND STRENGTH OF CHAIRSIDE SOFT LINERS TO DENTURE BASE RESIN – AN IN VITRO STUDY"** is a bonafide record work done by **Dr. N. RAJA GANESH** under our guidance and to our satisfaction during his post graduate study period between 2009 – 2013.

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ABSTRACT

Purpose of the study: Studies regarding the shear bond strength of chairside soft liners to heat polymerized denture base resin are few and limited. Hence the present study was conducted in vitro to comparatively evaluate the shear bond strength of two chair side, soft relining materials namely autopolymerizing plasticized acrylic resin and silicone based liner bonded to heat polymerized Poly methylmethacrylate denture base resin before and after thermocycling and to characterize the mode of interfacial bond failure using scanning electron microscopy.

Materials and Methods: Forty test specimens (n =40) were prepared by bonding plasticized acrylic based softliner and silicone based softliner to heat polymerized acrylic resin blocks. Twenty specimens, ten each from acrylic and silicone based liner groups were subjected to thermocycling. All the forty specimens were then subjected to shear bond strength testing in an universal testing machine. The debonded specimens were then qualitatively analysed for the mode of failure using scanning electron microscopy. The results were tabulated and statistically analysed.

Results: The mean shear bond strength values obtained for acrylic based soft liner before and after thermocycling were 0.3365 ±0.025 MPa and 0.3164 ±0.04 MPa respectively. The mean shear bond strength values obtained for silicone based soft liner before and after thermocycling were 0.4159 ±0.025 MPa and 0.4335±0.02 MPa respectively. Scanning electron microscopy analysis showed a predominantly mixed mode of failure with silicone based liner and predominantly adhesive mode of failure with acrylic based soft liner.

Conclusion: The silicone based softliner showed higher shear bond strength to heat polymerized acrylic resin than acrylic based soft liner both before and after thermocycling.

Keywords: softliner, heat polymerized acrylic resin, themocycling, shear bond strength.

INTRODUCTION

A conventional removable prosthesis relies on the residual alveolar bone for its support. The masticatory load and functional forces are directed to the underlying residual alveolar bone through the mucoperiosteum in complete denture or partial denture wearers. The soft denture bearing mucosa is confined between the hard denture base and bone. The condition of the bearing tissues may be adversely affected by high stress concentrations during function which can cause considerable damage to the supporting tissues resulting in chronic soreness, pathologic changes, and bone loss[8]. These conditions can be resolved by relining procedure of removable prosthesis.

Relining is a procedure used to resurface the tissue side of a denture with a new base material, thus producing an accurate adaptation to the denture foundation area. A denture may be relined as a laboratory procedure or at the chair side in the dental clinic. Relining ill-fitting removable dentures improve their stability, support and retention[45]. Autopolymerized resilient liner materials allow the clinician to reline a removable denture directly intra orally. This method is not only faster than using heat polymerized liner materials (laboratory processed) but also can reproduce the morphologic features of oral soft tissues directly on the denture base and avoid the need for patients to be without the denture for any period of time[40]. Further, this method has been frequently used to prolong the life of reasonable dentures, particularly when the construction of a new one is either not possible or suitable due to the

health of the patient or the condition of the denture bearing tissues not being appropriate. The chair side relining procedure with the soft denture liner is used extensively in prosthodontics because of the simplicity of the technique, and the good fit of the prosthesis obtained

A soft liner material is used to reline the removable dental prosthesis. It is defined as a soft resilient material bonded to the fitting surface of a denture to achieve a more equal distribution of the load to residual ridges. Soft denture liners have a key role in modern removable prosthodontics because of their capability of restoring health to inflamed and distorted mucosa. They are resilient, viscoelastic materials used to form part of the fitting surface of a denture. They act as a cushion for the denture bearing mucosa through absorption and redistribution of forces transmitted to the stress bearing areas of edentulous ridges, provide more equal force distribution, reduce localized pressure and improve denture retention by engaging undercuts.

Soft Denture Liners also offer a valuable solution in the management of painful or fragile mucosa or ulcerated tissues associated with the wearing of dentures and provide comfort for patients who cannot tolerate occlusal pressures, such as in cases of alveolar ridge resorption, chronic soreness, and knife–edge ridges. These materials have been found useful for treating patients with bony undercuts, bruxing tendencies, congenital or acquired oral defects requiring obturation, xerostomia, dentures opposing natural dentition in the opposing arch and for transitional prosthesis after implant surgery.

The ideal properties for a soft liner include resilience, tear resistance, viscoelasticity, biocompatibility, lack of odor and taste, adhesive bond strength, low solubility in saliva, low adsorption in saliva, ease of adjustability, dimensional stability, color stability, lack of adverse effect on denture base material, resistance to abrasion and ease of cleaning.

The ISO (International Organization for Standardization) categorizes a short term resilient liner as one used intraorally for a period of upto 30 days. They are also called as temporary soft liners or tissue conditioners. They are used for surgical procedures, diagnostic procedures, immediate placement of transitional removable partial dentures, immediate dentures, and other temporary situations to aid the healing of the tissues in contact with the denture. Liners intended to be used over a period of 1-6 months are categorized as intermediate liners. These are made of plasticized acrylic. They usually last for 1-2 months when placed in removable prosthesis, after which the liner loses the plasticizer and becomes stiff. Long term liners are intended to be used for up to 1year or longer. These are otherwise called as permanent liners and are used on complete dentures where it is necessary to absorb masticatory loads, and are indicated for patients who are unable to tolerate the pressures transmitted by the denture to the underlying mucosa of the edentulous ridge. They are mainly used when preprosthetic surgery is not indicated but the patient presents with bony undercuts or poor residual ridge anatomy, such as knife-edge ridge[22].

Soft or resilient liners can be classified as room temperature vulcanized (RTV) and heat temperature vulcanized (HTV). Soft liners can be divided into 4 groups according to their chemical structure: a) plasticized acrylic resin either chemical or heat cured, b) vinyl resin, c) polymethane and poly phosphazine rubbers (d) silicone rubbers[8].

Contemporary resilient liner materials can be classified as short term liners or long term liners. They can be divided into 2 groups depending on the chemical composition as acrylic resin based and silicone based. Both groups are available in auto polymerized or heat polymerized forms.

Acrylic resin based resilient liner materials generally consist of polymers and monomers. The composition of the polymers and monomers is proprietary, but these materials generally include methacrylate polymers and copolymers, along with a liquid containing methacrylate monomer and plasticizers (ethyl alcohol and\or phthalate). Plasticized polymethyl methacrylate (PMMA) and PMMA denture base materials are similar in chemical structure and so bonding agents are considered unnecessary for these materials. Acrylic based soft liners have disadvantages such as unpleasant odor and taste, and irritation to the soft tissue inside the mouth which can be attributed to their monomer content.

Silicone based resilient lining material is similar in composition to silicone impression materials as both are dimethylsiloxane polymers. Polydimethylsiloxane is a viscous liquid that can be cross linked to form a

rubber with good elastic properties. Softness of these liners is controlled by the amount of cross-linking in the rubber and no plasticizer is necessary to produce a softening effect with this material. Silicone liners have little or no chemical adhesion to PMMA resins and an adhesive is supplied to aid in bonding the liner to the resin denture base. Silicone liners keep their softness for a longer period than acrylic resin liners[50].

The choice of a soft liner for clinical use should be based on the materials biocompatibility, mechanical properties and durability in the oral environment. Definitive and interim resilient denture liners have differing uses and should be selected based on the desired service time of the material. Interim resilient liners are acrylic resin based and may harden at a faster rate and have superior elastic qualities than the definitive materials. Therefore interim liners are widely used as tissue conditioners or temporary relines.

There are several problems associated with the use of resilient denture liners, including bond failure between the liner and the denture base, colonization by candida albicans, porosity, poor tear strength, and loss of softness. One of the most serious problems with these materials is bond failure between the resilient denture liner and denture base. The interfacial bond between the denture base and resilient liner is of much importance since the ability of the liner to effectively absorb and uniformly transmit the masticatory stresses is dependent on the integrity of the bond. Bond failure creates a potential surface for bacterial growth, and plaque and calculus formation.

The weakened bond strength promotes the ingress of oral fluids and microorganisms at their interface and finally results in separation of the reline material from the denture base. A variety of parameters affect the bond between resilient lining materials and the denture base, including water absorption, surface primer use, denture base composition and temperature changes. It is therefore essential that there is an adequate bond between the denture base and the soft lining material. Failure of soft lining materials is often attributed to a breakdown of this bonding and thus the measurement of bond strength is very important.

The most commonly used methods to measure the bond strength of soft liners to denture base materials are peel, tensile or shear tests. Though tensile bond strength of various lining materials to different denture base resins have been investigated by many authors, shear forces best represent the clinical situation in which the resilient liners function. Studies on shear bond strength of resilient liners to denture base resin are limited.

Soft denture liners are expected to function in the aqueous oral environment for long periods of time as well as under rapidly changing temperatures. However it must be noted that with cyclic temperature, the thermal behaviors of the structural components within a material can influence the latter’s mechanical, physical properties and the bond strength. In this connection, the thermocycling process can give useful data on the longevity of soft denture liners with respect to bond strength under conditions that simulate

clinical usage. The effect of thermo cycling on the tensile bond strength of denture liners has been widely reviewed by authors. Adequate data on the effect of thermocycling on the shear bond strength of soft liners is lacking which is more critical than tensile loading.

The paucity of data on shear bond between denture reline and denture base polymers prompted the current study, the purpose of which was to characterize the shear bond strength between two chair side denture reline materials and denture base polymers. Hence, this study was conducted for comparative evaluation of shear bond strength of two chair side, soft relining materials namely autopolymerizing plasticized acrylic resin and silicone based liner bonded to heat polymerized Polymethyl methacrylate denture base resin before and after thermocycling and to characterize the mode of interfacial bond failure.

The objectives of the present study were as follows:

1. To evaluate the shear bond strength of auto polymerizing plasticized acrylic soft liner to heat polymerized denture base resin before thermocycling.
2. To evaluate the shear bond strength of auto polymerizing plasticized acrylic soft liner to heat polymerized denture base resin after thermocycling.
3. To evaluate the shear bond strength of silicone based soft liner to heat polymerized denture base resin before thermocycling.

4. To evaluate the shear bond strength of silicone based soft liner to heat polymerized denture base resin after thermocycling.
5. To compare the shear bond strength of auto polymerizing plasticized acrylic soft liner to heat polymerized denture base resin before and after thermocycling.
6. To compare the shear bond strength of silicone based soft liner to heat polymerized denture base resin before and after thermocycling.
7. To compare the shear bond strength of auto polymerizing plasticized acrylic soft liner and silicone based soft liner to heat polymerized denture base resin before thermocycling.
8. To compare the shear bond strength of auto polymerizing plasticized acrylic soft liner and silicone based soft liner to heat polymerized denture base resin after thermocycling.
9. To compare the overall shear bond strength of auto polymerizing plasticized acrylic soft liner and silicone based soft liner to heat polymerized denture base resin before and after thermocycling.
10. To characterise the mode of failure at the interface of auto polymerizing, plasticized acrylic soft liner and denture base resin before thermocycling.
11. To characterise the mode of failure at the interface of auto polymerizing, plasticized acrylic soft liner and denture base resin after thermocycling.

12. To characterise the mode of failure at the interface of silicone based soft liner and denture base resin before thermocycling.
13. To characterise the mode of failure at the interface of silicone based soft liner and denture base resin after thermocycling.

REVIEW OF LITERATURE

Thomas J.Emmer et al (1995)[19] evaluated the bond strength of five different soft lining materials (3 heat polymerized and 2 light polymerized) to heat processed PMMA resin using a new technique. The technique they developed represented an axial tensile mode of testing. The mode of failure was characterized using SEM analysis. Purely adhesive, purely cohesive, and mixed failures occurred depending on the type of relining material used.

Moodhy S.Al-Athel et al (1996)[3] did a comparative study to compare the peel, tensile, and shear bond strength values of a commonly used heat-cured denture soft-lining material (Molloplast-B) bonded to a poly methylmethacrylate denture base material. They also wanted to evaluate the effect of liner thickness and deformation rate of the bond strength. Their results showed that the highest tensile and shear strengths were obtained by specimens having the lowest liner thickness. Also, the deformation had a significant effect on Mollaplast-B tensile and shears strengths.

M.G.J.Waters et al (1999)[58] evaluated the mechanical properties of an experimental denture soft lining material. They compared the properties of commercially available denture soft lining material (Molloplast-B) with the experimental denture soft lining material. The experimental denture soft lining material with a new formulation incorporating alternative hydrophobic Silane-treated silica filler specimens were obtained by curing for 24hrs at room

temperature after the addition of the appropriate amounts of catalyst and cross-linker. Hardness, tear resistance, tensile strength and the bond strength of the material to a heat-cured acrylic denture base material of both the specimens were measured. They concluded that there was no significant difference in the hardness of the experimental denture soft lining material and Molloplast-B. The experimental denture soft lining material had superior tensile and tear properties. Its peel bond strength was superior to that of Molloplast-B, although its tensile bond strength and shear bond strength were less.

A.K.Aydin et al (1999)[8] did study to investigate the bonding properties of five lining materials to a denture base resin. Two hard liners (chemical cured resin "Kooliner" and light cured resin "Triad") and three soft liners (chemical-cured resin "Express", Heat-temperature vulcanized (HTV) silicone material, Molloplast-B and room-temperature vulcanized (RTV) Ufi Gel-P) were used. Bonding strength and adhesion properties of the liners to the conventional heat cured poly methylmethacrylate (PMMA) denture base resin were compared by tensile test and scanning electron microscope (SEM) analysis. After curing, an aging process was applied and the samples were immersed and stored in distilled water at 37± 1˚C and taken out at certain intervals at (0, 15, 30 and 90 days) for examination. A total of 168 specimens were processed for tensile tests and 24 specimens were processed for fracture tests. The results showed Triad (a hard liner) has the closest tensile strength to the control, indicating the strongest bonding between the base and the liner.

Also, during the aging process, formation of better adhesion was observed for Mollooplast-B in SEM micrographs. Molloplast-B and Express as resilient liners were found to have adequate adhesive values for clinical use.

Amany El-Hadary et al (2000)[17] studied the properties of water sorption, solubility and tensile bond strength of two soft liners. Their study evaluated and compared the water sorption, solubility and tensile bond strength of a recently introduced silicone-based soft liner (Luci-sof) and a plasticized acrylic resin soft liner (Permasoft) using 2 processing techniques-laboratory processed and auto polymerized at chair side. For water sorption and solubility testing, 24 disks (45 mm in diameter and 1mm in thickness) were prepared for each group, stored in distilled water at 37ºC, and tested after 1, 4, and 6 weeks. Their weight was recorded and sorption and solubility were calculated using 2 methods. The results showed Permasoft had higher solubility and sorption than Luci-sof after 6 weeks of aging. Luci-sof had significantly higher tensile bond strength than Permasoft. So on the basis of lower water sorption and solubility and higher tensile bond strength, Luci-sof provided better clinical success.

Yutaka Takahashi et al (2001)[57] had undertaken a study to characterize the shear bond strength established between four denture base polymers and four denture reline polymers. Specimens were immersed in water for four months and then thermocycled. The result showed significant difference in bond strength among the specimens because of the denture base

polymer variable, the denture reline polymer variable and their interaction. A light activated denture base polymer (Triad) bonded adequately with a light activated reline polymer (Triad) but less with the other reline polymers tested. The bond strength established between some denture base polymers and a different light activated reline polymer (Rebaron LC) was relatively low. They concluded that the type of denture base polymer and denture reline polymer affected the shear bond strength between them.

Yutaka Takahashi et al (2001)[56] also did another study to assess the shear bond strength between three denture reline materials and a denture base acrylic resin. Cylindric columns of denture reline materials were bonded to columns of denture base resins that received one of the following surface treatments: application of dichloromethane, the monomer of the denture base resin, the recommended bonding agent or the monomer of the denture reline material, polishing with 240grit silicon carbide paper and air abrasion. A control group without surface treatment was included for each material. Specimens were immersed in water for 1 day and then thermocycled. The result showed that the Triad bonding agent and denture base monomer should be used in conjunction with Triad and GC reline, respectively, when relining a denture base resin.

M. Al- Athel et al (2002)[4] did a study to know the effects of long term immersion in water at 37±1ºC and of accelerated ageing in water at 50± 1ºC on the tensile and shear bond strength values of Molloplast-B bonded to a heat

cured denture base material. Immersion in water for 1 week at 37± 1ºC had no significant effect on the measured bond strength values. They concluded that reduction in Molloplast-B bond strength that occurs as a result of long term ageing of water at 37±1ºC can be achieved in a shorter period of time by ageing the specimens in water at a higher temperature.

Robert G.Jagger et al (2002)[29] studied the effect of roughening the denture base surface on the tensile and shear bond strengths of a poly (dimethylsiloxane) resilient material bonded to a heat cured acrylic resin denture base material. Three groups of 10 specimens each were constructed for both tensile and shear tests. In the first group, Molloplast-B was packed against cured PMMA denture base surface. In the second group Molloplast-B was packed against PMMA denture base roughened with acrylic bur. In the third group, Molloplast-B was packed against PMMA denture base acrylic resin dough. In the result Molloplast-B exhibited significantly higher tensile and shear bond strengths when packed against acrylic resin dough. Roughening the denture base surface prior to the application of Molloplast-B had a statistically significant weakening effect on tensile bond strength compared with the smooth denture base and the acrylic resin dough. For the shear bond strength, roughening the surface produced a non-significant increase compared with the smooth surface, but the bond was weaker than when packed against acrylic resin dough.

John F. McCabe et al (2002)[39] studied the peel bond strength and tensile bond strength between three polyvinylsiloxane denture soft liners and a heat cured acrylic resin denture base using two adhesive systems. The results explained a consideration of stress concentrations at the soft-hard material interface during 180^0 testing. Adhesives based on ethyl acetate solvents produced stronger bond strengths, predominantly adhesive whereas that for ethyl acetate based adhesives was predominantly cohesive. Overall, the least resistance to peeling was exhibited by a material of low compliance (i.e.,relatively stiff) bonded with a toluene based adhesive. When an ethyl acetate based adhesive was used, all materials exhibited a resistance to peeling with a predominantly cohesive mode of failure.

Yasemin Kulak Ozkan et al (2003)[32] did a study on the effect of thermocycling on tensile bond strength of six silicone based resilient denture liners namely Ufigel C, Ufigel P, Molloplast-B, Mollosil, Permafix, and permaflex. The bond strength was determined, in tension after processing to PMMA. Half of the specimens for each group were stored in water for 24 hrs and the other half were thermocycled (5000 cycles) between baths of 5◦ C and 55◦C. The maximum tensile stress before failure and mode of failure were recorded. The mode of failure was characterized as cohesive, adhesive, or mixed mode. Results of this study also indicated that the bond strengths of soft lining materials had significantly decreased after thermocycling except

Ufigel C and Mollosil. The adequate adhesive value for soft lining materials is given as 4.5 kg/cm^2 and all of the materials were acceptable for clinical use.

Hiroyuki Minami et al (2004)[41] did an in vitro study to evaluate the effects of surface treatments and thermocycling on the bonding of auto polymerizing silicone soft denture liner (Sofreliner) to denture base resin. The bonding surfaces of denture base cylinders were polished with 600 grit silicon carbide paper and pretreated with applications of sofreliner primer, sofreliner primer after air abrasion, Reline Primer, or Reline Primer after air abrasion. Failure loads and elongation at failure were measured after subjection specimens to 0, 10,000, 20,000 and 30,000 thermocycles. The results proved the failure loads of the Sofreliner Primer group were significantly higher than those of the air abrasion group up to 20,000 thermocycles. They concluded that cyclic thermal stress is one factor degrading the bond between soft denture liner and acrylic resin denture base.

Jose Renato Ribeiro Pinto et al (2004)[51] conducted an in vitro study to evaluate the effect of varying amounts of thermal cycling on bond strength and permanent deformation of two resilient denture liners bonded to an acrylic resin base. Plasticized acrylic resin (PermaSoft) or silicone (Softliner) resilient lining materials were processed to a heat polymerized acrylic resin. Specimen liner thickness were standardized and were divided into 9 groups and were thermo cycled for 200, 500, 1000, 1500, 2000, 2500, 3000, 3500 and 4000 cycles. Controlled specimens were stored in water at 37◦C. The silicone

Softliner groups presented adhesive failure (100%) regardless of specimen treatment. PermaSoft groups presented adhesive (53%), cohesive (12%) or a combined mode of failure (35%), thus indicating that bond strength and permanent deformation of the two resilent denture liners tested varied according to their chemical composition.

Blanca Liliana Torres Leon et al (2005)[35] did a comparative study of water sorption, solubility, and tensile bond strength of two resilient liner materials polymerized by different methods after being thermal cycled. Two acrylic resin based resilient materials were evaluated one (Light Liner) polymerized by visible light liner and one (Ever Soft) processed by two different methods: hot water bath and microwave energy. Light Liner showed the lowest solubility values. Ever soft should be polymerized by microwave energy to obtain the greatest tensile bond strength values. Materials polymerized by microwave energy and visible light showed predominantly adhesive/cohesive failures.

Mustafa Murat Mutluay et al (2005)[43] evaluated the adhesion of chair side hard relining materials to denture base polymers. Significant differences were found among tensile bond strengths of chair side hard relining materials to PMMA denture base polymers. They concluded that the chemical composition of the bonding agents and the relining materials and their combination affected the depth of the swollen layers of the denture base polymers and the tensile strength of adhesion.

Duygu Sarac et al (2006)[53] did a study on the micro leakage and bond strength of a silicone based resilient liner following denture base surface pretreatment. Forty two PMMA denture base resin specimens consisting of two plates measuring 30 x 30 x 2 mm were prepared and divided into seven groups. Specimens were surface treated by immersing in acetone or methyl methacrylate and methylenechloride. One group with no surface treatment was served as the control group. The results showed that treating a denture based acrylic resin surface with chemical etchants prior to adhesive application reduced the micro leakage and increased the bond strength when using silicone based resilient liners. However, these chemical treatments decreased the flexural strength of the acrylic resin when compared to the untreated group.

Karin Hermana Neppelenbroek et al (2006)[45] assessed the shear bond strength of four hard chair side reline resins to a rapid polymerizing denture base resin (QC-20) processed using two polymerization cycles (A or B) before and after thermocycling. Cylinders (3.5mm x 5.0 mm) of the reline resins were bonded to cylinders of QC-20 polymerized using cycle. A (boiling water 20 minutes) or B (boiling water, remove heat 20 minute; boiling water 20 minutes). For each reline resin/polymerization cycle combination, ten specimens were thermally cycled and the other ten were tested without thermal cycling. The result showed QC-20 displayed the lowest bond strength values in all groups. In general, the bond strengths of the hard

chair side resins were comparable and not affected by polymerization cycle of QC-20 resin and thermal cycling.

Andrea Azevedo et al (2007)[9] did a study to evaluate the effect of water immersion on the shear bond strength between chairside reline and denture base acrylic resins. The effect of water immersion on the shear bond strength between one heat polymerizing acrylic resin (Lucitone 550-L) and four autopolymerizing reline resins (Kooliner-K, New Truliner-N, Tokuso rebase fast-T, Ufi gel Hard-U) was investigated. Shear tests were performed on the specimens after polymerization and after immersion in water at 37ºC for 7, 90 and 180 days. All fractured surfaces were examined by scanning electron microscope (SEM) to calculate the percentage of cohesive fracture (PCF). They concluded their study saying that the long term water immersion did not adversely affect the bond of materials Kooliner, New Truliner, Tokuso rebase and Ufi gel hard and decreased the values of resin Lucitone. Materials Lucitone 550-L and Ufi gel hard failed cohesively and Kooliner, New Truliner and Tokuso rebase failed adhesively.

Ayese Mese et al (2008)[40] did a study to evaluate the effect of storage duration on the tensile bond strength and hardness of acrylic-resin and silicone based resilient liners that were either heat or auto polymerized onto denture base acrylic resin. The denture liners investigated were a definitive heat polymerized acrylic resin based (Vertex Soft), interim auto polymerized acrylic resin based (Coe-Soft), definitive heat polymerized silicone based

(Molloplast-B), and definitive auto polymerized silicone based (Mollusil Plus) resilient liner. The resilent liners were processed according to manufacturer's instructions. The definitive heat polymerized silicone based Molloplast-B resilient liner had significantly higher bond strength and lower hardness values than the others. Prolonged exposure to water produced significantly higher hardness values and lower bond strength values, which suggested that the use of this resilient liner may not provide long term clinical success.

Caio Hermann et al (2008)[28] studied the effect of aging by thermal cycling and mechanical brushing on resilient denture liner hardness and roughness. A plasticized acrylic resin (Dentuflex) and two silicone-based (Molloplast-B, Sofreliner MS) resilient denture liners were examined. Pre- and post-test roughness and hardness measurements were recorded using a Surfcorder SE 1700 and Shore A durometer Teclock GS-709, respectively. The results showed thermal cycling promoted increased hardness for Sofreliner MS and Dentuflex. Mechanical brushing promoted wear abrasion in Sofreliner MS and Dentuflex materials. Molloplast-B experienced no deleterious effects from either of the tests.

Daniela Maffei Botega et al (2008)[12] evaluated the effects of thermocycling on the tensile bond strength of three permanent soft denture liners (PermaSoft, Dentuflex and Ufi-gel). Ten specimens were prepared for control and test groups of each material for a total of 60 specimens. All controls were stored in water (37ºC) for 24 hours before testing. All test

groups received 3000 thermal cycles consisting of 1 minute at 5ºC and 1 minute at 65ºC. All specimens were submitted to a tensile test using a universal testing machine at a crosshead speed of 5mm/min. Despite presenting greater bond strength, thermocycling had a deleterious effect in Dentuflex; Ufi-gel may be adequate for short term use.

Fauziah Ahmad et al (2009)[1] did a study to evaluate the shear bond strength of light polymerized urethane dimethacrylate (Eclipse) and heat polymerized polymethylmethacrylate (Meliodent) denture base polymers to intra oral and laboratory processed reline materials. Thirty disks measuring 15mm diameter and 2mm thick were prepared for each denture base material following the manufacturer's recommendations. They were relined with Meliodent RR, Kooliner, and Secure reline materials after one month of water immersion. Ten additional Eclipse specimens were relined using the same Eclipse resin. Meliodent denture base showed adhesive, cohesive and mixed failure, while all Eclipse showed adhesive failure with various reline materials. The two chemically different denture base polymers showed different shear bond strength values to corresponding reline materials.

Neeraja Mahajan et al (2010)[37] did an in vitro study on the comparison of bond strength of Auto polymerizing and Heat cure Soft denture liners with denture base resin. The tensile bond strength of two commercially available silicone based heat cured (Molloplast-B) and auto polymerizing (Mollosil) soft denture liners to denture base material (Trevalon)

was compared. Lloyds Universal testing machine was used to test 60 samples. Results showed Molloplast-B having greater bond strength than Mollosil soft denture liner. It was even greater when packed against trevalon in an n-polymerized form than an already polymerized trevalon using primo adhesive. Both the soft lining materials used are acceptable for clinical usage.

Rahul Shyamrao Kulkarni et al (2011)[33] did this study to evaluate the effect of two surface treatments, sandblasting and monomer treatments, on tensile bond strength between two long term resilient liners and poly methyl methacrylate denture base resin. Two resilient liners Super-Soft and Molloplast-B were selected. Each group was surface treated by sandblasting, monomer treatment (for 180 sec) and control (no surface treatment). The result showed monomer pretreatment of acrylic resin produced significantly higher bond strength for both the liners when compared to monomer pretreatment and control. They concluded that surface pretreatment of the acrylic resin with monomer prior to resilient liner application is an effective method to increase bond strength between the base and soft liner. Sandblasting on the contrary, is not recommended as it weakens the bond between the two.

Mohammad Q. Al Rifaiy et al (2011)[5] to assess the bonding characteristics of Triad VLP direct hard reline resin to heat polymerized denture base resin subjected to long term water immersion. Ninety circular disks, 15mm in diameter and 3mm thick of denture base resin were polymerized from a gypsum mold. Thirty water immersed specimens were

dried with gauze (group 1), 30 water immersed specimens were dried with a hair dryer (group 2) the remaining dry specimens represented the control group (group 3). All specimens were air abraded and painted with bonding agent before packing Triad VLP direct hard reline resin. Specimens in each group were subjected to thermal cycling for 50,000 cycles between 4ºC and 60ºC water baths with one minute dwell time at each temperature. The results showed significant difference in mean shear bond strength among the specimens existed because of variable water content in the denture base resin. The mean shear bond strength for Group 3 (dry) was higher than group 2 (desiccated) and the lowest was group 1 (saturated).

Salah A. Mohammed et al (2011)[42] did their in vitro study to compare four silicone based soft liner materials (Permaflex and Molloplast, Ufi-gel SC and permafix) in shear bond strength, water sorption and solubility and surface roughness test. Seventy two specimens of four silicon based soft lining material was used, the specimens of shear bond strength test were subjected to tension in instron machine with speed rate was 0.5mm/min to measure shear bond strength by N/mm. The result indicated that permaflex shows better properties when compared with other soft liner materials and that hot cure polymerizing soft liner material showed proper properties when compared with auto polymerizing soft liner material.

Arun Kumar G et al (2011)[34] conducted a study to compare and evaluate the tensile bond strength, shear bond strength, and hardness of

two acrylic based and two silicone based soft lining materials currently used as denture base linings. The result showed GC reline having higher tensile bond and shear bond strength, whereas viscogel showed least value for hardness showing that it is the softest of the soft liners tested. The silicone based soft liners showed higher values for the properties of tensile bond strength; shear bond strength compared to acrylic based soft liners. This study showed that for the long term use of soft liners, GC reline is the material of choice, whereas for short term use such as for conditioning of tissues, extra soft viscogel is the material of choice.

Dhanraj M et al (2011)[15] did an invitro study to compare and evaluate the tensile bond strength of heat polymerized permanent acrylic soft liner with various surface pretreatments of denture base, and also to compare and evaluate the efficacy of various surface pre-treatments influencing the bond strength of the denture base with liners at varying time intervals in the presence of artificial saliva. They concluded that the surface pre-treatment of denture base significantly increased the tensile bond strength and adhesive capacity with resilient liners. Also it was inferred that the mechano-chemical surface pre-treatment with sandpaper abrasion followed by monomer application exhibited superior bond strength compared to the other methods.

Jessica Mie Ferriera Koyama Takahashi et al (2011)[55] did their study to evaluate the effect of different accelerated aging times on permanent

deformation and tensile bond strength of two soft chair side liners, acrylic resin (T) and silicone (MS) based. Different specimens were made for each test of each reliner. The specimens were submitted to accelerated aging for 2, 4, 8, 16, 32, and 64 cycles. Mann-Whitney test was done to compare the materials at different times and Kruskal-Wallis and Dunn tests were used for comparing aging intervals within a given reliner. The result showed MS with lower permanent deformation and higher tensile bond strength than T. Although T presented changes in those properties after accelerated aging, both materials might be suited for long term use.

Nishitha Madan et al (2012)[36] made a study to assess the effect of simulated mouth conditions reproduced with thermocycling on the tensile bond strength of two silicone based resilient denture liners with acrylic resin bases. Specimens were divided into a control group that was stored for 24 hours in water at 37ºC and a test group that was thermocycled (2500 cycles) between baths of 5ºC and 55ºC. Heat polymerized resilient denture liner Molloplast-B had higher tensile bond strength than auto polymerizing liner Mollosil regardless of thermocycling. The bond strength of Mollosil increased after thermocycling while that of Molloplast-B decreased after thermocycling.

MATERIALS AND METHODS

The present in vitro- study was conducted for comparative evaluation of shear bond strength of two chair side soft relining materials namely autopolymerizing plasticized acrylic resin and silicone based liner bonded to heat polymerized polymethyl methacrylate denture base resin, before and after thermocycling and to characterize the mode of interfacial bond failure.

The following materials and equipments were used for the study:

MATERIALS EMPLOYED:

- Laboratory putty material (Perfit, Huge dental material Co.Ltd, China) (Fig.1)
- Modelling Wax (Cavex hard setup wax) (Fig.2)
- Plaster of Paris (Ramaraju Mills Ltd., India) (Fig.3)
- Separating medium (DPI-Mumbai) (Fig.4)
- Heat cure acrylic resin (DPI-heat cure polymer and monomer) (Fig.5)
- Silicon carbide paper (3M ESPE) (Fig.6)
- Plasticized autopolymerzing acrylic based soft liner (Coe-Soft, GC USA) (Fig.7)
- Primer liquid (GC reline primer R) (Fig.8)
- Silicone based soft resilient liner (GC reline soft) (Fig.8)
- Petroleum Jelly (Teypal Industries Ltd) (Fig.9)
- Distilled Water (Diet. Pondicherry) (Fig.10)
- Dental flask and clamp (Jabbar, India) (Fig.11a)

- Rubber bowl & Spatula (classic, India) (Fig.11b)
- Wax Knife, Wax carver (Fig.11c)
- Acrylic Trimmers (Shofu, Japan) (Fig.12)

EQUIPMENTS USED:

- Acrylizer (Fig.13)
- Dental Lathe (Suguna Industries Ltd) (Fig.14)
- Sand blaster (Ideal Blaster, Delta Labs) (Fig.15)
- Automated Thermocycling Unit (Haake Willytec, Germany) (Fig.16)
- Universal testing Machine (Instron, Lloyd Instruments, UK) (Fig.17)
- Scanning Electron Microscope- Sputtering Machine (Fig.18)
- Scanning Electron Microscope (SA400N, Canada) (Fig.19)

Description of Thermocycler:

In this study, thermocycler (Haake, W15, Germany) was used for thermo cycling the test samples to simulate the temperature changes in the oral cavity. It consists of two water baths, each maintained at different temperatures. Bath one has temperature variation from 25˚C to 100˚C and bath two has temperature variation from -5˚C to 100˚C. The required cycles can be easily adjusted via display from 0-9999 cycles. It has automatic refills for the baths to compensate evaporation during the long duration test. It has an auto

start capability. Bath two is connected to a cooling device. The two baths are connected by a rolling unit with an open sample container in the centre for holding the test samples. The Open sample container with the test samples is immersed cyclically in baths of warm and cold water. Simulation of exposure of samples to various temperature fluctuations can reveal bond durability of the samples.

Description of the Universal Testing Machine:

The table top, universal testing machine was used to test for shear bond strength of the test samples used in this study (Instron, Lloyd instruments, UK). It consists of an upper chamber and a lower chamber, a display board to display the amount of force needed to fracture the samples. The upper member has a wedge grip to which one part of the sample is attached and the other end is attached to lower member. Whole Unit is attached to the computer for recording the results.

Description of the Scanning Electron Microscope:

In this present study, the surface of the test samples was analyzed using scanning electron microscope (SA400N, Canada). Scanning electron microscope uses a beam of highly energetic electrons to examine objects on a very fine scale. The specimens to be magnified are coated with a platinum layer to prevent the charging up and in order to increase the secondary emissions. Additional sputter coating with gold produces high contrast and resolution. The incident electron probe scans the sample surface and the

signals produced are used to modulate the intensity of a synchronously scanned beam on a CRT screen. The electrons which are back scattered from the specimen are collected to provide (i) topographical information if low energy secondary electrons are collected (ii) atomic number and reorientation information if the higher energy, back scattered electrons are used, or if the leakage current to the earth is used. The magnification is given immediately by ratio of the CRT scan size to the specimen scan size.

METHODOLOGY

I. Fabrication of custom made stainless steel mold

II. Fabrication of heat polymerized acrylic denture base resin blocks

a. Preparation of wax blocks

b. Flasking procedure

c. Dewaxing procedure

d. Packing of acrylic resin

e. Curing procedure

f. Deflasking procedure

g. Finishing and polishing

h. Storage of acrylic blocks

III. Preparation of the bonding surface

IV. Incorporation of resilient liner material onto the bonding surface of heat polymerized acrylic resin blocks

a. Assembling of acrylic resin blocks and Teflon jig

b. Bonding of acrylic based soft liner to heat polymerized acrylic resin blocks

c. Bonding of silicone based soft liner to heat polymerized acrylic resin blocks

V. Grouping of test samples

VI. Thermocycling of samples

VII. Shear bond strength testing of the sample

VIII. Qualitative analysis of bond strength and mode of failure by Scanning Electron Microscopy (SEM)

IX. Statistical Analysis

I. Fabrication of custom made stainless steel mold (Fig.20,21)

A custom, cuboidal stainless steel mold of dimension 14 x 14 x 25 mm was milled. The purpose of the mold was to serve as a template for duplication from which wax blocks of similar dimension can be obtained and then be converted to acrylic resin blocks.

II. Fabrication of heat polymerized acrylic denture base resin blocks (Fig. 22-31)

a. Preparation of wax blocks : (Fig.22-24)

The custom made stainless steel mold was invested in laboratory putty material (Fig.22). Once the investing material got set, the stainless steel mold was retrieved, thus creating a hollow mold space of dimension 14 x 14 x 25mm. Modeling wax was then melted and poured into the mold space and allowed to cool (Fig.23). After the wax has hardened, the wax blocks were

retrieved carefully and placed in a container of distilled water at room temperature. 40 such wax blocks were fabricated (Fig.24).

b. Flasking procedure: (Fig.25)

The wax blocks were invested in a denture flask using type II dental plaster (Fig.25). A two pour technique was followed for flasking the wax specimens. Type II dental plaster was mixed with water using a stainless steel straight spatula in rubber bowl and poured into the lubricated base portion of the denture flask. The wax blocks were placed into the mix. The number of samples per denture flask was restricted to a maximum of four to ensure adequate space between the samples. After the plaster had set, separating medium was painted over the plaster surfaces, and the lubricated body of the flask was placed over the base. It was filled with a fresh mix of type II dental plaster and the lid was closed. The denture flask was tightened with a flask carrier and the excess plaster removed.

c. Dewaxing procedure: (Fig.26)

The plaster was allowed to harden for 1 hour before the denture flask was placed in a boiling water bath. The flasks were placed in boiling water for 15 minutes. The flasks were removed from the water and the appropriate segments of the flask were carefully separated in a vertical direction to avoid fracture of the invested plaster. The softened wax was flushed out from the surface of the mold with hot water. Wax solvent and warm detergent solution

were used to remove wax residues and oily films respectively. Finally the molds were flushed well with clean hot water. Both the halves of the flasks were placed on end for several minutes to allow the water to drain completely. The flasks were allowed to cool completely prior to packing. After dewaxing, rectangular mold spaces in the base of the denture flask is ready for the packing of acrylic resin (Fig.26).

d. Packing of acrylic resin: (Fig.27)

A thin coating of separating medium was painted on a plaster surface. Heat cure acrylic resin was mixed in the porcelain cup with a powder/liquid ratio as per the manufacturer's instructions. The porcelain cup was closed with a lid until the mix reached the dough stage. Required quantity of acrylic resin was packed individually into each rectangular mold space (Fig.27). The two halves of the flask were closed and the flask was placed under the bench press and tightened. The excess resin extruding from the flask was removed.

e. Curing procedure:

The packed denture flasks were bench cured for 60 minutes as per the manufacturer's instructions and the flasks were removed from the bench press. The flasks were tightened under their respective flask carriers and placed in the acrylizer for resin polymerization. A curing cycle of 74˚C for approximately 2 hours and then increasing the temperature of the water bath to

100˚C and processing for 1 hour as per standard recommendations was followed for all packed test specimens.

f. Deflasking procedure: (Fig.28)

After the completion of polymerization cycle, the flasks were removed from the water bath and bench cooled for 30 minutes and then kept under running tap water for 15 minutes. Following this, the deflasking of the specimens was done (Fig.28).

g. Finishing and polishing: (Fig.29,30)

After the specimens were deflasked and excess plaster was removed, acrylic burs were used to trim excess resin. Sandpapers of grit sizes of 100 and 120 respectively were used to smoothen the surface, mounted on a sandpaper mandrel (Fig.29). A total of 40 heat polymerized acrylic blocks were obtained in a similar manner (Fig.30).

h. Storage of acrylic blocks :

The prepared 40 acrylic resin blocks were stored in distilled water at 37± 1º C for 50±2 hours for the denture base polymer to reach water saturation. This procedure was adopted to simulate the effect of saliva during denture wear before relining.

III. Preparation of bonding surface: (Fig.31)

The denture base resin surface to bonded was smoothed on silicon carbide paper to simulate clinical relief of the denture base for bonding of the reline resins. The bonding surfaces of the acrylic blocks were air abraded with 50μm aluminum oxide particles under 0.5MPa of pressure for 6 seconds (Fig.31). The surfaces were then brushed with liquid detergent for 20 seconds, washed with distilled water and blot dried.

IV. Incorporation of resilient liner material onto the bonding surface of heat polymerized acrylic resin blocks (Fig.32-40)

a. Assembling of acrylic resin blocks and Teflon jig: (Fig.32-34)

A cylindrical Teflon jig, 24mm in diameter and 6mm in height was fabricated. The jig had a closed end and an open end. The closed end had a central circular opening, 6mm in diameter and 3mm in height so as to limit the bonding of the soft liner to a circular area of 6mm diameter and standardize the height of the soft liner to 3mm (Fig.32a,b,c).

The custom made Teflon jig was placed on the surface treated end of the acrylic resin block. The design of the jig was such that the resin block fits snugly into the internal surface of the cylindrical jig (Fig.33). Thus the assembly serves the dual purpose of delineating the shape and size of the bonding area and preventing the soft liner from contacting the acrylic resin surface outside the circular bonding area (Fig.34).

b. Bonding of acrylic based soft liner to heat polymerized acrylic resin blocks : (Fig.35-37)

The autopolymerizing acrylic based liner material was mixed following the manufacturer's instruction in the ratio of 8ml of liquid and 11gms of powder in a glass cup and stirred for 30 seconds (Fig.35). The material was then carried with the help of a packing instrument on to the bonding area and packed into the centre of Teflon cylinder (Fig.36). An acetate sheet was placed over the material and pressure was applied until polymerization was completed. After the soft liners has set, the Teflon jig is removed and the test samples of acrylic blocks with acrylic based soft liner, of height 3mm bonded to a circular area of 6mm in the centre of resin blocks were obtained (Fig.37). This process was carried out for 20 acrylic resin blocks, to obtain 20 test samples of acrylic based soft liner.

c. Bonding of silicone based soft liner to heat polymerized acrylic resin blocks : (Fig.38-40)

For the silicone lining material, the primer liquid supplied by the manufacturer was applied to the bonding area using a clean dry camel hair brush and was allowed to dry (Fig.38). The silicone based soft liner which is supplied in cartridges was mixed using a hand held auto mixing device and was introduced into the bonding area (Fig.39). An acetate sheet was placed over the material and pressure was applied until polymerization was completed. The working time for silicone liner is 2 minutes and it is allowed

to set for 5 minutes. After the soft liner has set, the Teflon jig is removed and the test samples of acrylic blocks with silicone based soft liner, of height 3mm bonded to a circular area of 6mm in the centre of resin blocks were obtained (Fig.40). This process is carried out for the remaining 20 acrylic resin blocks to obtain 20 samples of silicone based soft liner.

V. Grouping of test samples: (Fig.41)

A total of forty (n=40) test samples were thus obtained and randomly distributed into 4 groups as follows:

Group A1 – plasticized acrylic resin based soft liner bonded to heat polymerized acrylic resin blocks (n=10, control group).

Group A2 - plasticized acrylic resin based soft liner bonded to heat polymerized acrylic resin blocks submitted to thermocycling regimen (n=10, test group).

Group S1 – silicone based soft liner bonded to heat polymerized acrylic resin blocks (n=10, control group).

Group S2 - silicone based soft liner bonded to heat polymerized acrylic resin blocks submitted to thermocycling regimen (n=10,test group).

Ten test samples (n=10) of each test group were stored in distilled water for 24 hours at room temperature before subjecting to thermocycling and shear bond strength testing.

VI. Thermocycling of samples: (Fig.42)

All the ten (n=10) samples each of test groups A2 and S2 were subjected to thermo cycling for a total of 250 cycles in a distilled water bath between 5˚C and 55˚C with a dwell time of 60 seconds and a dry time of 10 seconds at 27 ºC between the warm and cold cycles using a thermo cycling apparatus (Haake, W15, Germany).(Fig.42) Upon completion of thermo cycling, the specimens were stored in distilled water in their respective containers until they were subjected to shear bond strength testing.

VII. Shear bond strength testing of the samples: (Fig.43-47)

A total of forty samples (Groups A1, A2, and S1andS2) were tested for shear bond strength in an universal testing machine (Instron, Llyod instruments, UK). Each test sample was fixed to the sample fixture at the bench vice of the machine with a knife edged chisel blade positioned parallel to the material interface (Fig.43). Force was applied to the sample in such a way that shear load was exerted directly to the bonding interface at a cross head speed of 1 mm/min until failure of the bond occurred (Fig.44,45). The tests were conducted in air at room temperature. Load deflection curves and ultimate load to failure were recorded automatically and displayed by the computer software of the testing machine. Shear bond force at which the bond failed was recorded in Newton and shear bond strength (MPa) was calculated by dividing the force (N) at which failure of the bond occurred by the surface area of adhesion (mm^2). The tested samples were stored in distilled water.

Bond Strength (MPa) =Force (N) /surface area (mm^2)

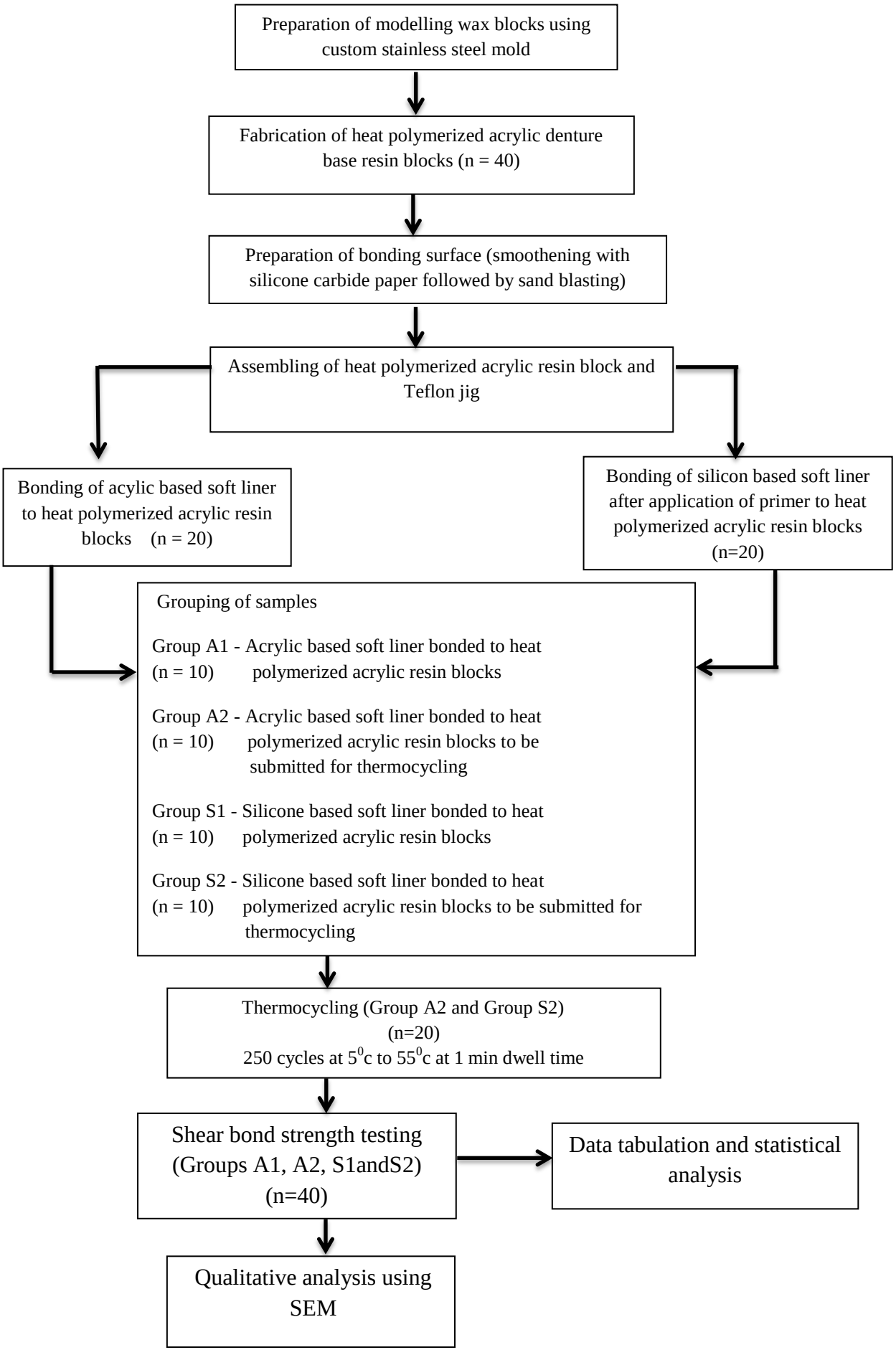
VIII. Qualitative analyses of bond strength and mode of failure by scanning electron microscopy (SEM): (Fig. 46-59)

Surface analysis was carried out on one representative sample per test group selected randomly using scanning electron microscope (SA400N, Canada). The samples were secured into Cu stubs with double adhesive tapes and coated with a layer of gold using gold sputtering system (Fig.46). Coated samples were examined under SEM to qualitatively assess the surface topography of surface treated samples at 14x, 50x and 150x magnifications (Fig.47). The mode of failure of tested samples was assessed under these magnifications (Fig.48-59).

IX. Statistical analysis:

The basic and mean value data of shear bond strength obtained were tabulated individually for all the 4 test groups (Group A1, A2, S1 and S2) and was statistically analyzed. The statistical analysis were performed using SPSS Software (SPSS for Windows 10.05, SPSS software Corp. Munich, Germany) using Independent ‘t’ test and paired ‘t’ test.

METHODOLOGY – OVERVIEW



MATERIALS

Fig.1: Laboratory Putty Material

Fig.2: Modelling Wax

Fig.3: Plaster of paris

Fig.4: Separating medium

Fig.5: Heat cure acrylic resin

Fig.6: Silicone carbide paper

Fig.7: Plasticized autopolymerizing acrylic based soft resilient liner

Fig.8: Silicone based soft resilient liner

Fig.9: Petroleum jelly

Fig.10: Distilled water

Fig.11: Dental flask, Clamp, Rubber bowl, Spatula, Wax knife and Wax carver

Fig.12: Acrylic trimmers

EQUIPMENTS

Fig.13: Acrylizer

Fig.14: Dental lathe

Fig.15: Sand blaster

Fig.16: Thermocycler

Fig.17: Universal testing machine

Fig.18: Scanning Electron Microscope - Sputtering machine

Fig.19: Scanning Electron Microscope

METHODOLOGY

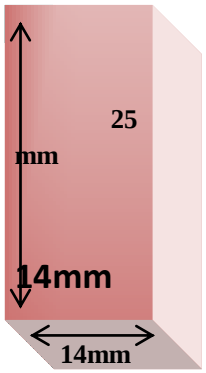


Fig.20: Schematic diagram of stainless steel mold

Fig.21: Stainless steel mold

Fig.22: Stainless steel mold duplicated in lab putty

Fig.23: Wax template within mold space

Fig.24: Prepared wax blocks

Fig.25: Invested wax blocks

Fig.26: Dewaxed mold

Fig.27: Packing of acrylic resin

Fig.28: Deflasking

Fig.29: Finishing of the acrylic resin blocks

Fig.30: Finished acrylic resin blocks

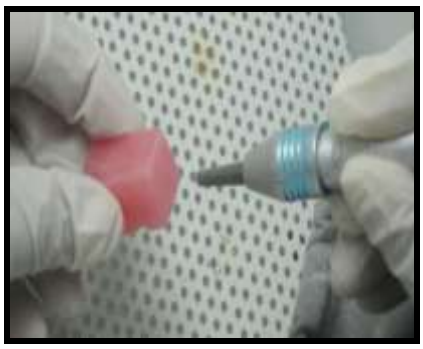


Fig.31: Air abrasion of resin block

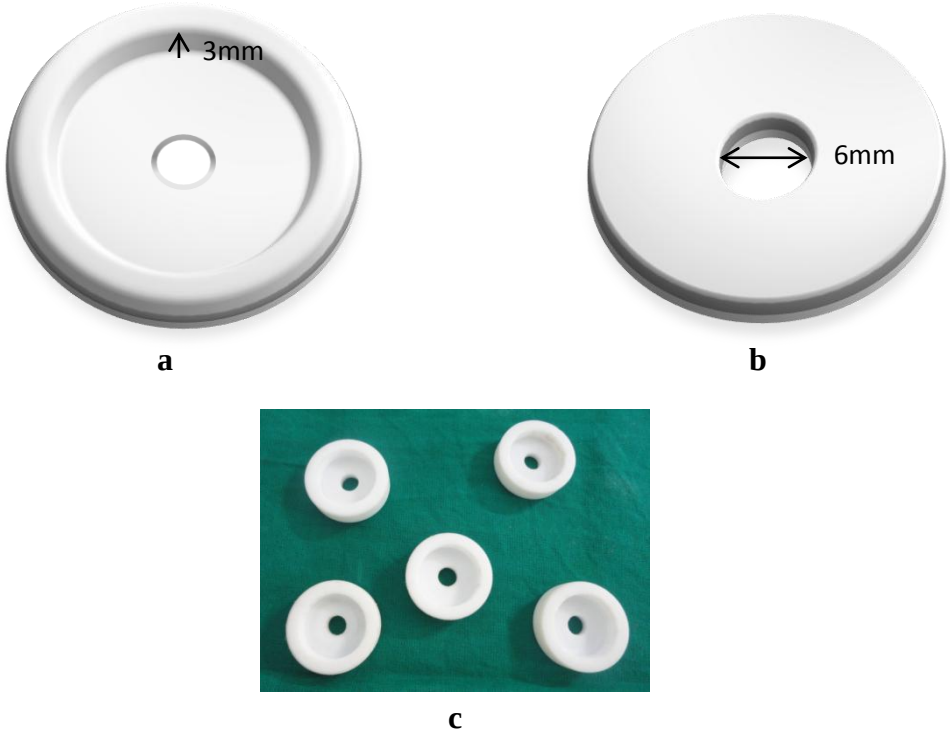


Fig.32a,b & c: Custom made Teflon jig

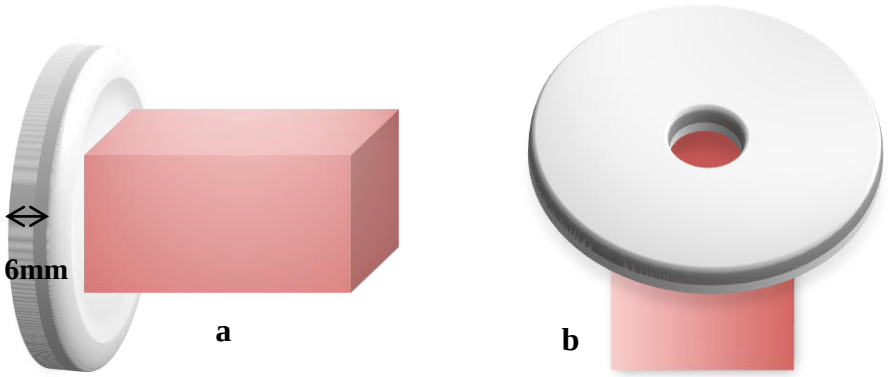


Fig.33a,b: Schematic representation of Assembly of Teflon jig –Acrylic resin block

Fig.34: Assembly of Teflon jig – Acrylic resin block

Fig.35: Mixing of acrylic based soft liner

Fig.36: Incorporation of acrylic based soft liner in Teflon cylinder

Fig.37: Finished, bonded samples of acrylic based soft liner

Fig.38: Primer application prior to silicone liner bonding

Fig.39: Incorporation of silicone based soft liner

Fig.40: Finished, bonded samples of silicone based soft liner

Fig.41: Grouped test samples stored in distilled water

THERMOCYCLING & SHEAR BOND STRENGTH TESTING OF THE SAMPLES

Fig.42: Thermocycling

Fig.43: Test specimen mounted on universal testing machine

Fig.44: Shear bond strength testing of acrylic based softliner

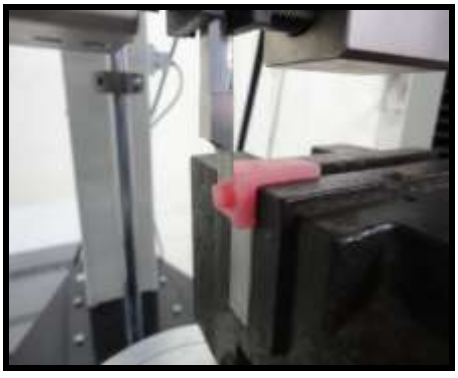


Fig.45: Shear bond strength testing of silicone based softliner

Fig.46: Gold sputtering prior to SEM analysis

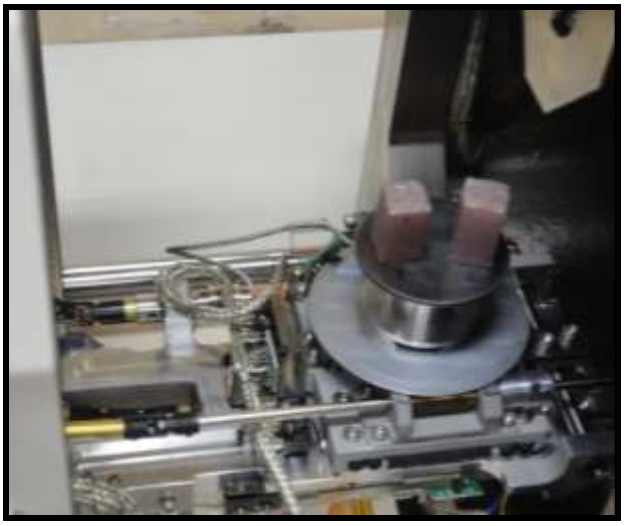


Fig.47: Surface analysis using scanning electron microscopy

RESULTS

The present in vitro study was conducted for comparative evaluation of shear bond strength of two chair side, soft relining materials namely autopolymerizing plasticized acrylic resin and silicone based liner bonded to heat polymerized Poly methylmethacrylate denture base resin before and after thermocycling and to characterize the mode of interfacial bond failure.

Forty samples (n= 40) of resilient liners of dimension 6 mm diameter and 3 mm height were bonded to heat polymerized acrylic resin blocks. The samples were divided into four groups as follows:

Group A1 – plasticized acrylic resin based soft liner bonded to heat polymerized acrylic resin blocks (n=10, control group).

Group A2 - plasticized acrylic resin based soft liner bonded to heat polymerized acrylic resin blocks submitted to thermocycling regimen (n=10, test group)

Group S1 – silicone based soft liner bonded to heat polymerized acrylic resin blocks (n=10, control group).

Group S2 - silicone based soft liner bonded to heat polymerized acrylic resin blocks submitted to thermocycling regimen (n=10, test group).

One representative tested sample from each test group (Group A1, Group A2, Group S1 and Group S2) was randomly selected and qualitatively

analyzed using Scanning electron microscopy under 14x, 50x and 150x magnifications. The mode of failure was characterized using the SEM data.

The following results were drawn from the study:

Tables 1 to 4 show the Basic values and Mean Value of Shear bond Strength for groups A1, A2, S1 and S2.

Table 5 shows the Comparison of Mean and Standard Deviation of Shear bond strength of Acrylic Based Soft Liner before (Group A1) and after (Group A2) Thermocycling.

Table 6 shows the Comparison of Mean and Standard Deviation of Shear bond strength of Silicone Based Soft Liner before (Group S1) and after (Group S2) Thermocycling

Table 7 shows the Comparison of Mean Shear bond strength of Acrylic Based Soft Liner and Silicone Based Soft Liner before Thermocycling (Group A1 with Group S1).

Table 8 shows the Comparison of Mean Shear bond strength of Acrylic Based Soft Liner and Silicone Based Soft Liner after Thermocycling (Group A2 with Group S2).

Table 9 Shows the overall comparison of the mean shear bond strength values of Acrylic Based Soft Liner and Silicone Based Soft Liner before and after Thermocycling. (Groups A1,A2,S1 and S2)

Table 1: Basic values and Mean Value of Shear bond Strength for Acrylic based Soft liner before thermocycling (Group A1)

Sample No	ShearBond Strength in MPa
1	0.324339
2	0.34816
3	0.38353
4	0.32771
5	0.29897
6	0.3324
7	0.36087
8	0.35037
9	0.30616
10	0.33158
Mean	**0.3364089**

Inference

Table 1 shows the maximum shear bond strength value of 0.3835 MPa and minimum value was 0.2989 MPa. The mean shear bond strength was 0.3364 MPa.

Table 2: Basic values and Mean Value of Shear bond Strength for Acrylic based Soft liner after thermo cycling (Group A2)

Sample No	ShearBond Strength in MPa
1	0.36695
2	0.37579
3	0.35645
4	0.33103
5	0.25089
6	0.29179
7	0.31445
8	0.29952
9	0.30118
10	0.27576
Mean	**0.316381**

Inference

Table 2 shows the maximum shear bond strength value of 0.3757 MPa and minimum value was 0.2508 MPa. The mean shear bond strength was 0.3164 MPa.

Table 3: Basic values and Mean Value of Shear bond Strength for Silicone based Soft liner before thermo cycling (Group S1)

Sample No	Shear Bond Strength in MPa
1	0.38021
2	0.41779
3	0.42000
4	0.40010
5	0.45869
6	0.44100
7	0.40840
8	0.37911
9	0.42663
10	0.42774
Mean	**0.41597**

Inference

Table 3 shows the maximum shear bond strength value of 0.4586 MPa and minimum value was 0.3791 MPa. The mean shear bond strength was 0.4159 MPa.

Table 4: Basic values and Mean Value of Shear bond Strength for Silicone based Soft liner after thermo cycling (Group S2)

Sample No	Shear Bond Strength in MPa
1	0.40287
2	0.44155
3	0.44542
4	0.43326
5	0.40895
6	0.41558
7	0.43989
8	0.46311
9	0.42608
10	0.45813
Mean	**0.43348**

Inference

Table 4 shows the maximum shear bond strength value of 0.4631 MPa and minimum value was 0.4028 MPa. The mean shear bond strength was 0.4335 MPa.

Table 5: Comparison of Mean and Standard Deviation of Shear bond strength of Acrylic Based Soft Liner before (Group A1) and after (Group A2) Thermocycling.

Independent 't' test

Groups	No of Test Samples	Mean (MPa)	Standard Deviation	'p' Value
A1	10	0.3365000	0.0250000	0.194
A2	10	0.3163800	0.0400000	

Note: 'p' value < 0.05 denotes statistical significance.

Inference

The Shear Bond Strength of acrylic based soft liner decreased after thermocycling. Since the p value (0.194) is greater than 0.05 the decrease is not statistically significant.

Table 6: Comparison of Mean and Standard Deviation of Shear bond strength of Silicone Based Soft Liner before (Group S1) and after (Group S2) Thermocycling.

Independent 't' test

Groups	No of Test Samples	Mean (MPa)	Standard Deviation	'p' Value
S1	10	0.4159700	0.0250000	0.101
S2	10	0.4334900	0.0200000	

Note: 'p' value < 0.05 denotes statistical significance.

Inference

The Shear Bond Strength of silicone based softliner increased after thermocycling. Since the p value (0.101) is greater than 0.05, the increase is not statistically significant.

Table 7: Comparison of Mean Shear bond strength of Acrylic Based Soft Liner and Silicone Based Soft Liner before Thermocycling (Group A1 with Group S1).

Independent 't' test

Groups	No of Test Samples	Mean (MPa)	Standard Deviation	'p' Value
A1	10	0.3365000	0.0250000	0.0001*
S1	10	0.4159700	0.0250000	

Note: 'p' value < 0.05 denotes statistical significance.

* denotes statistically significant difference.

Inference

The Silicone Based soft liner had exhibited higher Shear Bond Strength value than the Acrylic Based soft liner before thermocycling. Since the 'p' value is less than 0.05 (0.0001) there is a significant difference between the two groups.

Table 8: Comparison of Mean Shear bond strength of Acrylic Based Soft Liner and Silicone Based Soft Liner after Thermocycling (Group A2 with Group S2).

Independent 't' test

Groups	No of Test Samples	Mean (MPa)	Standard Deviation	'p' Value
A2	10	0.3163800	0.0400000	0.0001*
S2	10	0.4334900	0.0200000	

Note: 'p' value < 0.05 denotes statistical significance.

* denotes statistically significant difference.

Inference

The Silicone based soft liner had exhibited higher Shear Bond Strength value than the Acrylic Based soft liner after thermocycling. Since the 'p' value is less than 0.05 (0.0001) there is a significant difference between the two groups.

Table 9: Overall Comparison of the Mean Shear bond strength values of Acrylic Based Soft Liner and Silicone Based Soft Liner before and after Thermocycling (Groups A1, A2, S1 and Group S2)

GROUP	**Shear bond strength values before thermocycling (MPa)**	**Shear bond strength values after thermocycling (MPa)**	**'p' Value**
Acrylic based softliner	0.3365	0.3164	0.194
Silicone based softliner	0.4160	0.4335	0.101
'p' value	0.0001*	0.0001*	

Note: 'p' value < 0.05 denotes statistical significance.

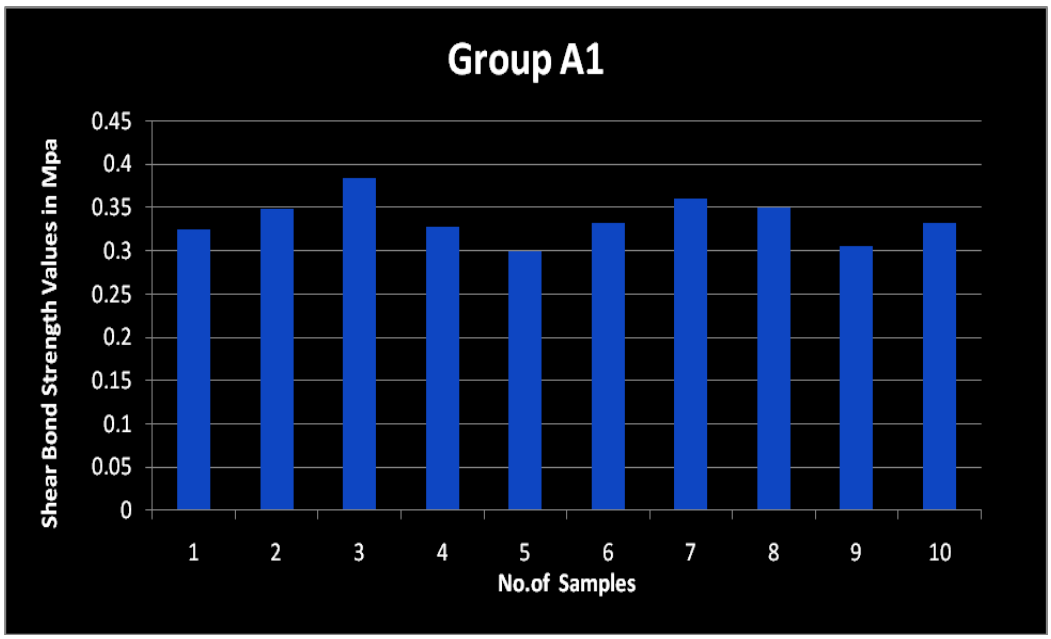
* denotes statistically significant difference.

Inference:

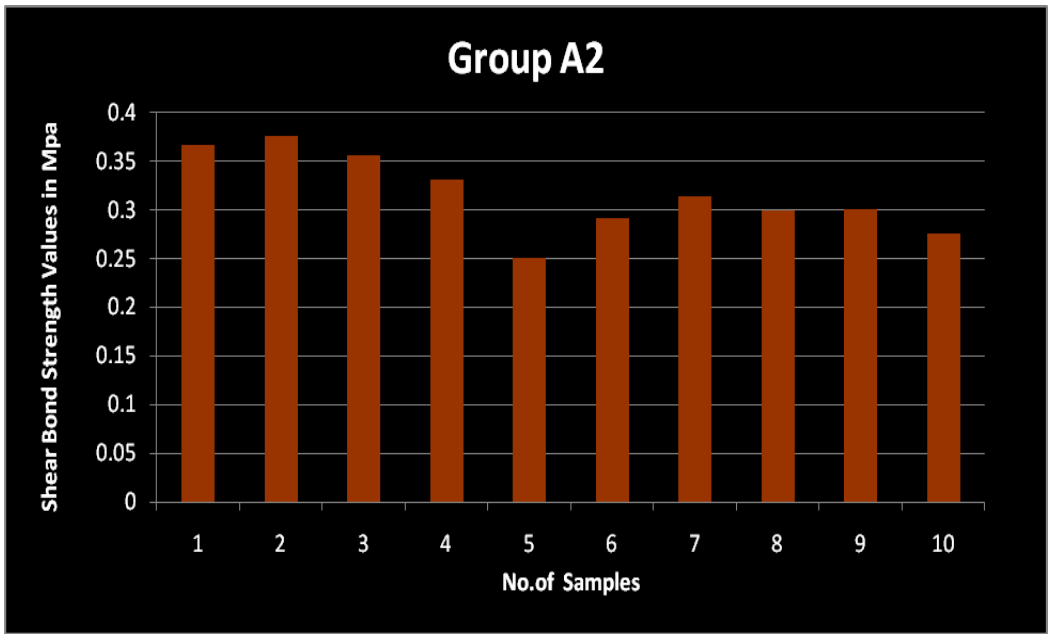
Shear bond strength of silicone based softliner were higher than that of acrylic based softliner both before and after thermocycling and this difference was statistically significant.

Shear bond strength of acrylic based softliner reduced after thermocycling, while it increased for silicone based softliner. But the differences were statistically not significant.

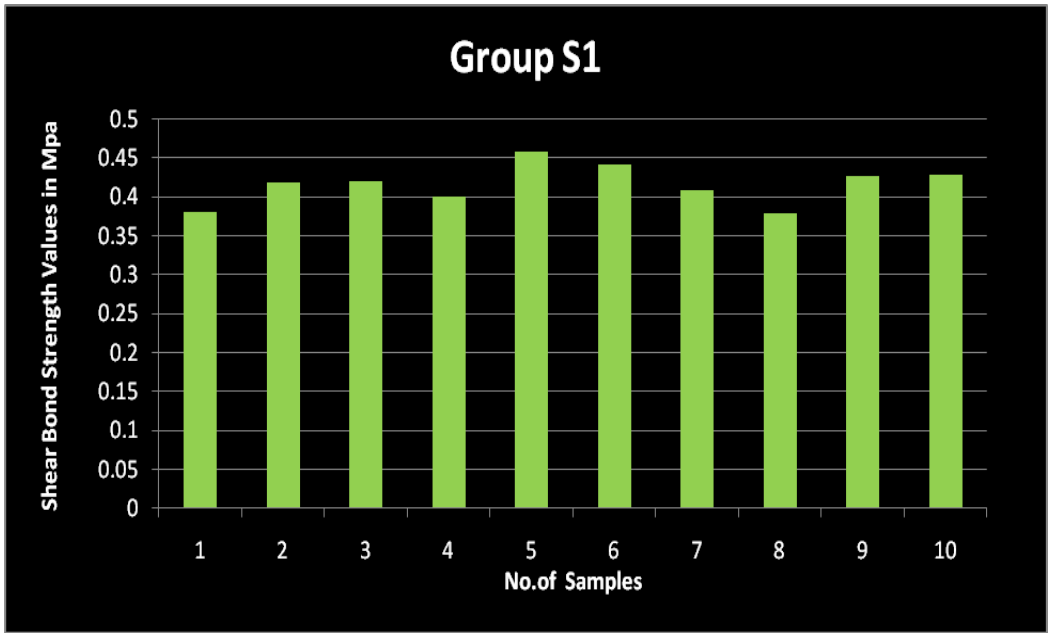
Graph 1: Basic Values of shear bond strength for acrylic based soft liner before thermocycling (Group A1)



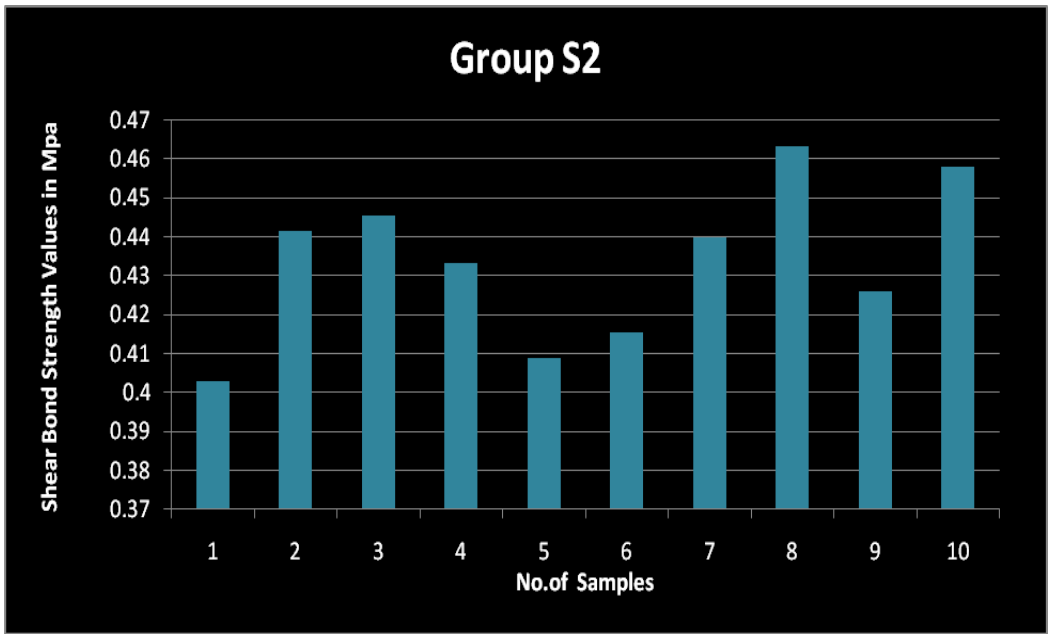
Graph 2: Basic Values of shear bond strength for acrylic based soft liner after thermocycling (Group A2)



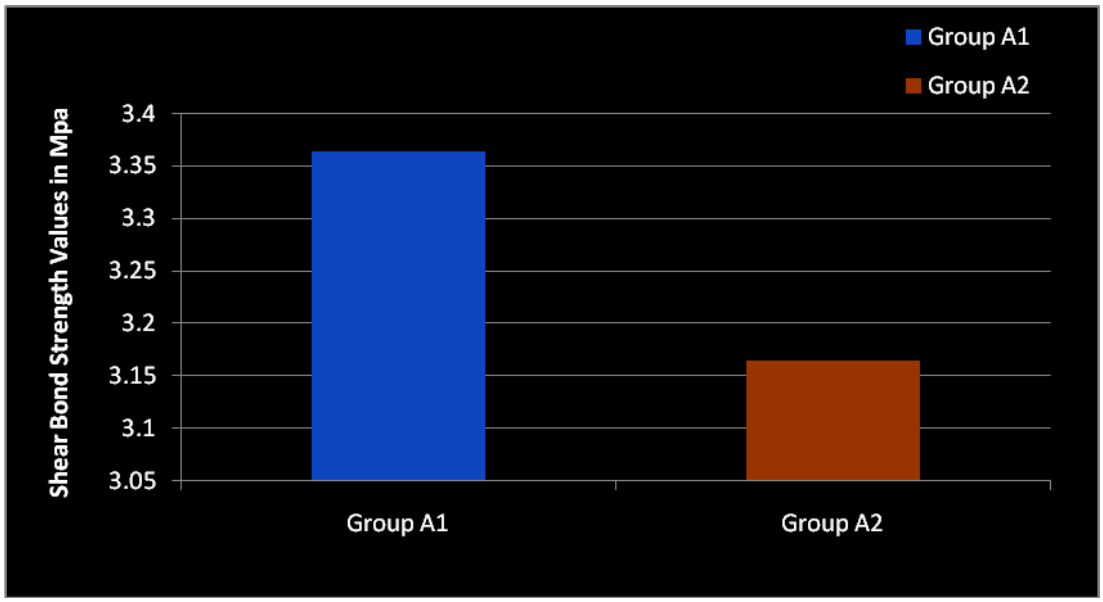
Graph 3: Basic Values of shear bond strength for silicone based soft liner before thermocycling (Group S1)



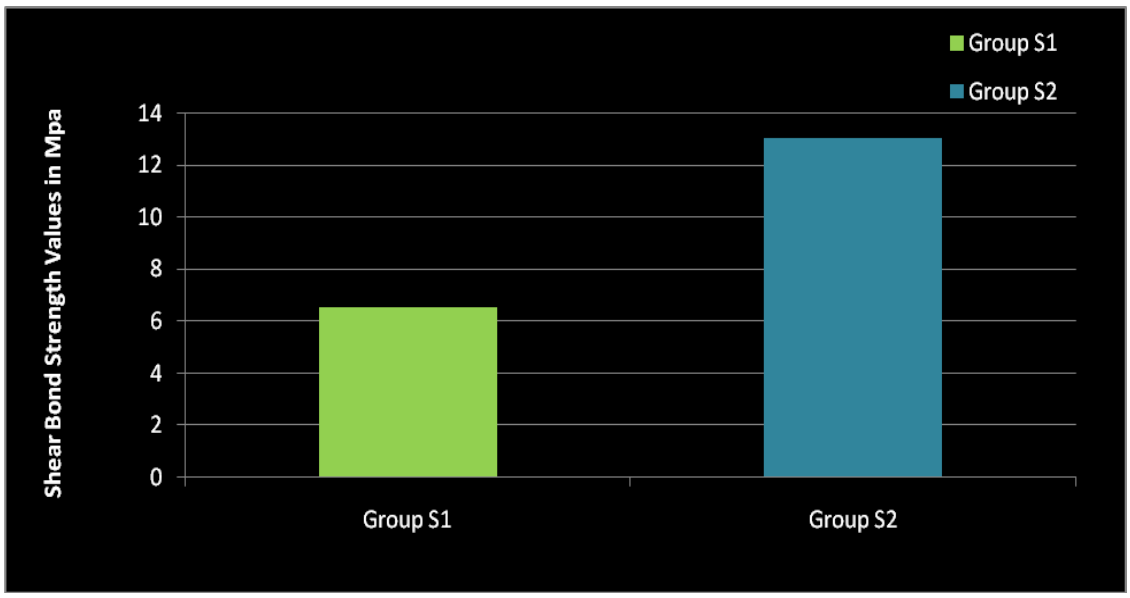
Graph 4: Basic Values of shear bond strength for silicone based soft liner after thermocycling (Group S2)



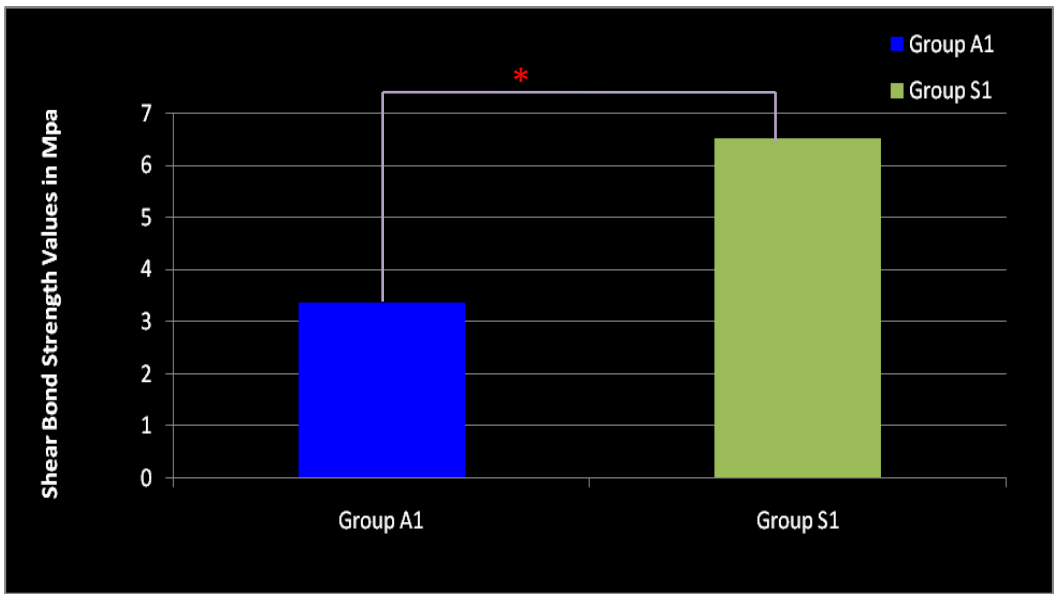
Graph 5: Comparison of mean shear bond strength of acrylic based soft liner before (Group A1) and after (Group A2) thermocycling



Graph 6: Comparison of mean shear bond strength of silicone based soft liner before (Group S1) and after (Group S2) thermocycling

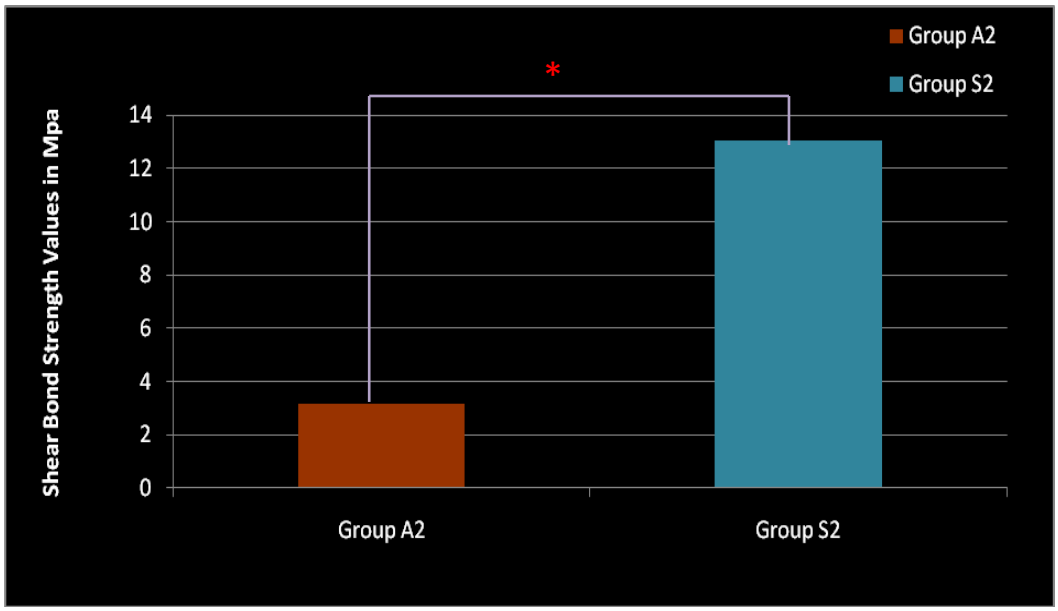


Graph 7: Comparison of mean shear bond strength of acrylic based soft liner and silicone based soft liner before thermocycling (Group A1 with Group S1)



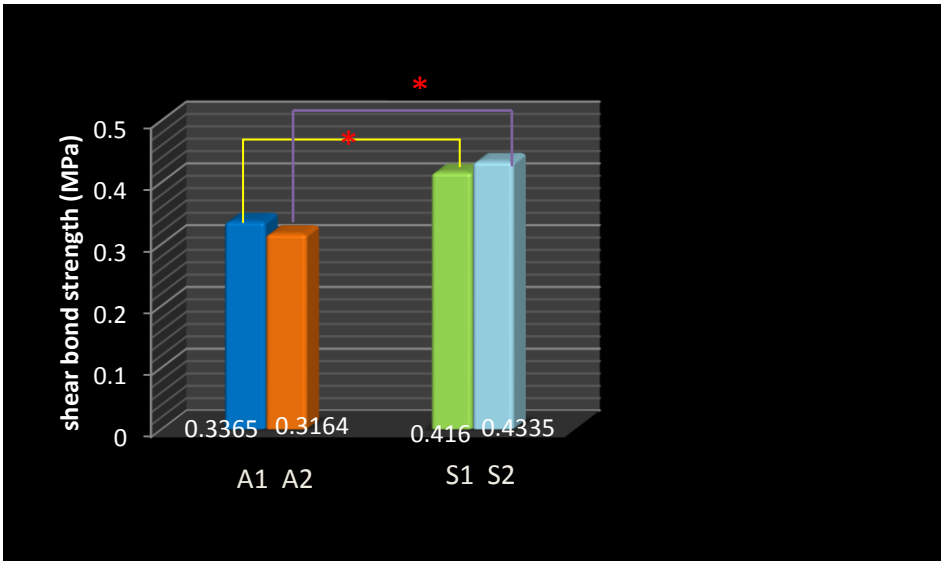
* Indicates significant difference at 5% interval

Graph 8: Comparison of mean shear bond strength of acrylic based soft liner and silicone based soft liner after thermocycling (Group A2 with Group S2)



* Indicates significant difference at 5% interval.

Graph 9: Overall comparison of the mean shear bond strength values of acrylic based soft liner and silicone based soft liner before and after thermocycling (Group A1, A2, S1, S2)



* Indicates significant difference at 5% interval

QUALITATIVE ANALYSIS OF BOND STRENGTH AND MODE OF FAILURE BY SCANNING ELECTRON MICROSCOPY (SEM)

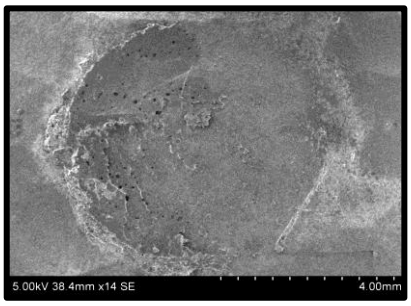


Fig.48: SEM photomicrograph of group A1- Acrylic based softliner before thermocycling under 14x magnification

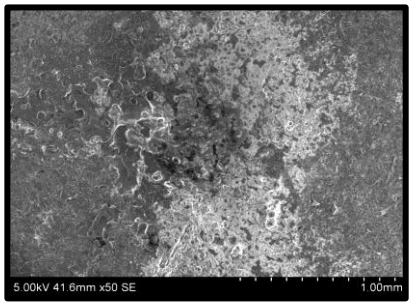


Fig.49: SEM photomicrograph of group A1- Acrylic based softliner before thermocycling under 50x magnification

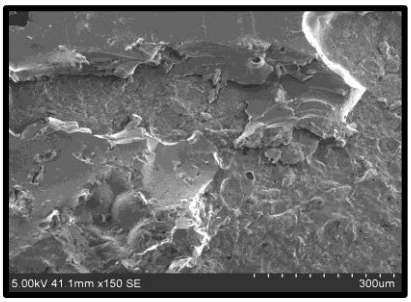


Fig.50: SEM photomicrograph of group A1- Acrylic based softliner before thermocycling under 150x magnification

Inference:

Under 14x magnification, the circular area of bonding of liner and acrylic resin, with scattered regions of liner attached to the acrylic resin were visible. A comparatively large surface of acrylic resin was visible with only a few scattered layers of liner material. Under 50x magnification, layers of liner material and acrylic resin surface were visible along with few voids. Under 150 x magnifications the tear in the layer of liner material and the surface of acrylic resin were seen along with voids and surface irregularities on both. This SEM observation indicates adhesive failure of acrylic based softliner before thermocycling.

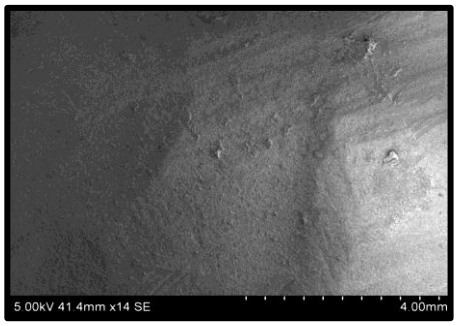


Fig.51: SEM photomicrograph of group A2 - Acrylic based softliner after thermocycling under 14x magnification

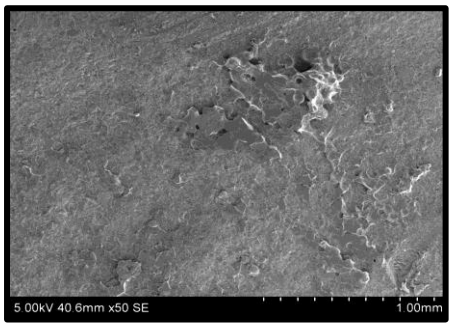


Fig.52: SEM photomicrograph of group A2 - Acrylic based softliner after thermocycling under 50x magnification

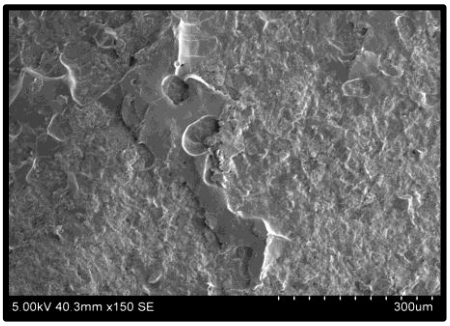


Fig.53: SEM photomicrograph of group A2 - Acrylic based softliner after thermocycling under 150x magnification

Inference:

Under 14x magnification, a large surface area of acrylic resin with a single island of liner material attached to it is seen. Under 50x magnification, a single isolated area of liner material surrounded by a large area of irregular acrylic resin surface was visible. Under 50x magnification, a thin layer of liner material attached to acrylic resin surface with irregularities and voids were visible. This SEM observation indicates adhesive failure of acrylic based softliner after thermocycling.

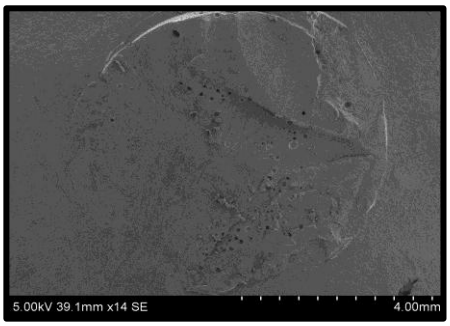


Fig.54: SEM photomicrograph of group S1- Silicone based softliner before thermocycling under 14x magnification

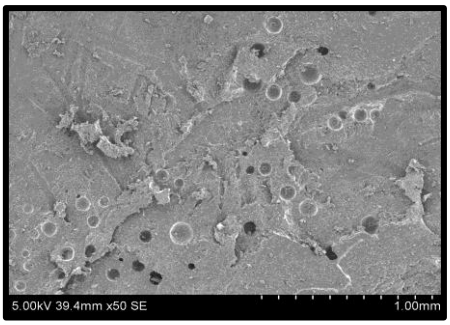


Fig.55: SEM photomicrograph of group S1- Silicone based softliner before thermocycling under 50x magnification

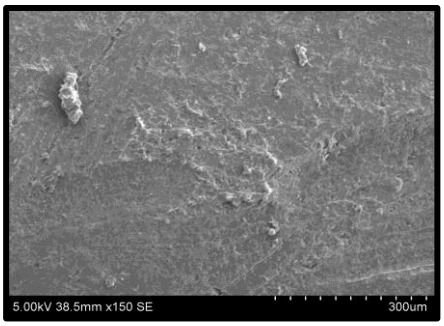


Fig.56: SEM photomicrograph of group S1- Silicone based softliner before thermocycling under 150x magnification.

Inference:

Under 14x magnification, the outline of the bonding area of liner-acrylic resin was visible. Another circular outline surrounding the liner was seen, which is inferred as the primer that was applied before the bonding of liner. Areas of adhesive, cohesive and mixed failure were seen. Under 50x magnification, the layers of liner materials with voids and acrylic resin with surface irregularities were seen. Under 150x magnification, isolated islands of liner and a large area of acrylic resin with surface irregularities were seen. This SEM observation indicates mixed mode of failure of silicone based softliner before thermocycling.

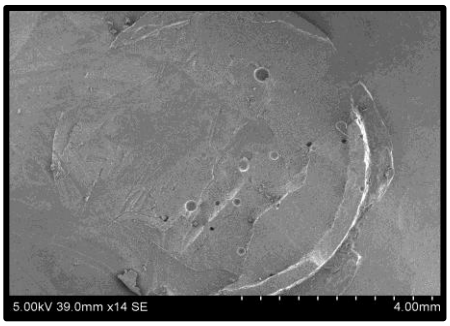


Fig.57: SEM photomicrograph of group S2 - Silicone based soft liner after thermocycling under 14x magnification

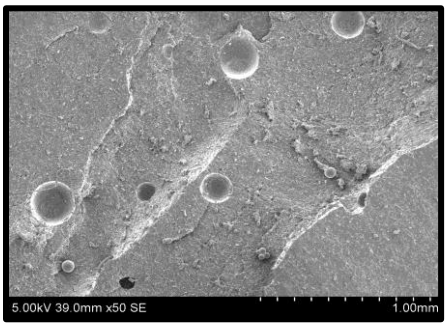


Fig.58: SEM photomicrograph of group S2 - Silicone based soft liner after thermocycling under 50x magnification

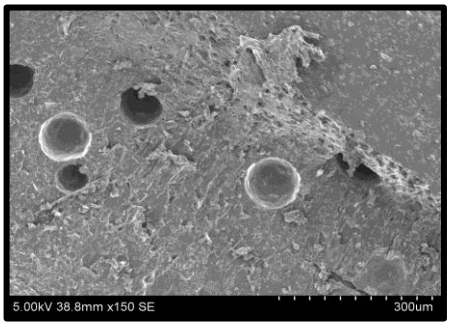


Fig.59: SEM photomicrograph of group S2 - Silicone based soft liner after thermocycling under 150x magnification

Inference:

Under 14x magnification a circular outline of the liner with few voids outside the layer of primer, surrounded by acrylic resin surface were seen. Under 50x magnification, layers of liner materials with small and large voids continuous with acrylic resin were visible. Under 150x magnification, layers of the liner material and areas of acrylic resin were visible. This SEM observation indicates mixed mode of failure of silicone based softliner after thermocycling.

DISCUSSION

The base of the denture is largely responsible for providing a removable prosthesis with retention, stability and support by being closely adapted to the oral mucosa. The retention of a denture is highly dependent on the accurate fit of the denture base to the underlying denture bearing tissue. However, the process of alveolar ridge resorption following tooth loss is irreversible and continuous which may lead to an inadequate fit of the prosthesis. Denture that has been satisfactory to both patient and dentist might gradually lose its stability and retention because of changes in supporting tissues or due to occlusal disharmony. Instability and poor fit are not only annoying to the patient but also detrimental to oral health. Excessive movement of the denture base may be a contributing factor to inflammation of tissues as well as papillary hyperplasia.

The accuracy of fit of an otherwise acceptable denture can be improved by adding a layer of new material onto the tissue surface. This process is usually referred to as Relining. Denture relining is indicated when the denture still retains proper vertical dimension, centric occlusion relationship and esthetic appeal. When the denture lacks one of these features in addition to compromised fit of denture base, re-fabrication of the denture should be contemplated. The relining process can be carried out either directly in the patient's mouth or in the laboratory. Both procedures have their own advantages and disadvantages. Chair side relining with a soft lining material is

widely used to treat abused mucosa, mitigate the effect of unfavourable denture foundation area such as bony undercuts, knife edge ridge etc., Though chair side relining is convenient and time saving, few authors have expressed concern regarding the irritation of oral tissues by the components of lining materials, locking of the liner into undercuts, change in the existing vertical dimension, etc., Laboratory relining on the other hand provides a more durable bond of the liner to the denture base resin and is often indicated for long term relining with a hard reline material.

Various studies have investigated the properties and performance of a wide array of relining materials commercially available. The physical, mechanical, biological and viscoelastic properties are well analysed and documented in the literature. The most important area of research with regards to soft liners continues to be the bond strength between the liner and the denture base. The two most commonly used soft lining materials are plasticized acrylics and silicone elastomers.

The present study was undertaken primarily to evaluate the shear bond strength of two commonly used soft chair side relining materials namely autopolymerizing plasticized acrylic resin (Coe soft) and vinyl poly siloxane elastomer (GC reline soft) to heat processed poly methylmethacrylate resin (DPI) which is a commonly used denture base material for removable prosthesis. Sufficient bond strength between the soft liner material and denture base is required to avoid the interfacial separation at the denture borders. Lack

of durable bond between the resilient liner and the denture is a common clinical problem [12]. The bond strength of the liner-denture base interface has been researched extensively by many authors. Al-Athel et al[3] studied the various bond strength assessment methods namely peel test, tensile bond strength and shear bond strength between the liner-denture base interface. He concluded that shear forces best represent the oral conditions in which the liner functions. Hence shear bond strength of the material is more indicative of its clinical longevity. The peel test is believed to simulate the horizontal component of masticatory forces as it causes lateral displacement of the denture. Tensile test on the other hand predominantly represents the vertical component of the masticatory force.

Bates & Smith[10] proposed that tensile bond strength test gives the information of the bond strength as such rather than the tensile strength of the material. But Fowler & Cantor et al pointed out that tensile failure was not caused by tensile forces alone because some shear forces were also developed during tensile testing. This is especially true in case of silicone lining material which has a high Poisson ratio. Such materials undergo a reduction in cross sectional area on tensile load application whereas the bonded portion of the liner maintains a constant area. This induces some shear forces at the margins of the bonded interface. Hence shear bond strength evaluation was adopted in this present study as a means to quantify the bonding capability of lining

material to the denture base resin. The qualitative analysis of the bond was done using SEM analysis of the bonded interface after shear bond testing.

The specimens for shear bond strength testing in the present study were fabricated in the form of cylindrical columns of liner material bonded to a circular area of denture base resin. The area of bonding was limited to a 6mm diameter circular region and height of the liner was kept at 3mm. This is in accordance to previous test sample designs employed. Ahmad Fouziah et al[1] and Azevedo Andrea[9] bonded cylindrical column of liner to the denture base using a metal mold, whereas Al Rifaiy[5] & Hasan[26] used Teflon tubes and masking tapes to delineate the bonding area.

In the present study, a custom made Teflon jig was fabricated which limited the dimensions of the liner and stabilized the acrylic blocks while bonding and also prevented the excess liner from flowing outside the confined area. Thus the use of masking tape was eliminated. Since the Teflon jig was milled, it had accurate dimensions and obviated the need for making individual templates for bonding as used in some previous studies. Also, Teflon being an inert material doesn't chemically reacts with either of the liners used in this study and also facilitated easy retrieval of the bonded specimens.

Few authors[18,25,34] advocated the use of specimens in which liner was introduced into the interface between two resin plates or blocks. These were called as 'lap shear 'specimen which were subjected to shear bond strength

testing. But the results obtained from the testing of such specimen should be interpreted with caution. Only an adhesive failure at the interface represents the actual shear bond strength of the liner to the denture base. A cohesive failure is an indication of the shear strength of the liner material used. Also, the liner is bonded to the denture base resin at two interfaces, whereas in the clinical scenario the bonding is only at one interface and the liner is in close adaptation to the denture bearing mucosa at the other interface. Hence the failure occurring when the liner debonds from one of the interfaces gives a lower than actual shear bond strength value since the liner is still bonded to the resin at the other interface.

Hence the specimen fabricated for use in this study closely resembles the clinical scenario with a single soft liner-denture base interface along which parallel shear forces can be applied to accurately find out the shear bond strength. The load at which the bond failed under shear stress was recorded in newtons and is taken as the shear load value of that particular specimen .The shear bond strength values in MPa were obtained by dividing the shear load values (N) by the cross sectional area of bonding. In the present study, since the bonding was confined to a circular area of 6mm diameter, the cross sectional area was calculated using the formula πr^2 (area of a circle). The bonding area of the specimens was around 28.274 mm^2 which was calculated as follows:

Bond Strength (MPa) =Force (N) /surface area (mm^2)

Bond Strength (MPa) =Force (N) / πr^2 = Force (N) / 3.14159 × 9

Bond Strength (MPa) =Force (N) / 28.274 mm^2

(Area of circle = πr^2, value of π = 3.14159, r = 3 mm)

The results of the present study showed that the acrylic based liners demonstrated lower shear bond strength values than the silicone based liners before and after thermocycling. The higher bond strength of the silicone based liners may be attributed to the improved adhesive bonding system used which usually contains silicone polymer in volatile solvents that is able to penetrate the acrylic resin[36]. The acrylic based liners though chemically similar to the resin denture base show lower bond strength because of the limited ability of the monomer to penetrate the resin and the varying degrees of polymerization seen. It has been proposed that highly cross linked denture or denture teeth polymers restrict the penetration of monomers because of the high density of the polymer network, and thus are not as effectively bonded.

The mean shear bond strength values obtained in this study for plasticized autopolymerizing acrylic resin based liner before and after thermocycling were 0.33650±0.025 MPa and 0.31638±0.04 MPa respectively. The mean shear bond strength values obtained for silicone base liner before and after thermocycling were 0.4159±0.025 MPa and 0.43349±0.02 MPa

respectively. It was noted that the auto polymerizing plasticized acrylic liners demonstrated a marginal decrease in the shear bond strength after thermo cycling, whereas the silicon based liners demonstrated a marginal increase. The decrease in the bond strength of acrylic based liners can be attributed to hydration and stress concentration at the bonding interface, in the presence of residual monomer. Furthermore, hydrolytic degradation of the bond occurs when water diffuses into the interface [41]. Silicon based liners on the other hand are hydrophobic and have very low water absorption. After thermocycling, silicone based liner showed an increase in bond strength, which may indicate that the material became more brittle and less viscoelastic. This can also be attributed to its continued polymerization, less water sorption and changes in the viscoelastic properties which increase the hardness of the liner[32]. It has been suggested that the filler particles present in these materials are responsible for the minimal water absorption seen (Anusavice 1996 and Bradin 1983). The improved bonding of the filler to resin by means of an acrylooxyl silane and the complete polymerization and cross-linking lead to less unreacted monomer and impurities, more dense material and therefore less water sorption.

Salah mohammed et al [42] conducted a study and determined the shear bond strength values of two chairside autopolymerizing silicone liner materials as 0.3 MPa and 0.328 MPa. Their values are similar to the values obtained for silicone liners in this study. In a study by Mese et al[40]

autopolymerizing acrylic softliner (Coe–soft) exhibited lower bond strength after ageing in water for 1 day. This is similar to the results obtained in the present study. Elias et al [18] acquired mean shear bond strength values in the range of 0.81± 0.02 MPa and 0.78± 0.04 MPa before and after thermocycling respectively. In his study, thermocycling had decreased the shear bond strength value of silicone liners whereas in the present study, the shear bond strength of thermocycled samples of silicone liner had exhibited higher value, but it does not have any statistical significance (p value = 0.161). Pinto et al[50] reported no significant difference in the bond strength values of autopolymerizing acrylic resin liner (permasoft) after thermocycling which is similar to the results obtained in the present study. Takahashi et al [56] reported mean shear bond strength of 2.2 MPa and 2.7 MPa for acrylic and silicone based liners respectively which belonged to a different manufacturer.

The bond strength values obtained, either tensile or shear vary widely depending upon a host of factors such as the materials used, prebonding surface treatments, ageing and thermal cycling etc. Also the specimen size, configuration of the specimen, thickness of the soft lining material, cross head speed, type of denture base resin, type of liner and processing techniques can influence the results[41]. Hence the values should be interpreted with caution and the results cannot be always extrapolated.

Hachim et al [25] obtained a shear bond strength value of 0.649 MPa for a silicone based soft liner bonded to heat processed acrylic resin, whereas in

the same study the same liner bonded to visible light cure denture base gave a mean shear bond strength value of 0.2432 MPa which indicates autopolymerizing liner material bonds poorly with light cured polymerizing denture base. This fact was also confirmed by Takahashi et al [56] in which visible light cure reline material gave the highest bond strength only when bonded with visible light cure denture base.

Craig and Gibbons (1961)[13] claimed that 0.44 MPa is an adequate tensile bond strength value for a soft liner, whereas Kawano et al[31] (1992) suggest that the failure stress should be atleast 0.96 MPa. Ahmad et al[1] obtained a bond strength of 4.5±0.5 MPa for acrylic based soft lining material (kooliner) bonded to heat polymerized PMMA resin which was significantly higher than the value of 2.21 ± 4 MPa obtained by Takahashi and chai[56] for the same material .They attributed this to a thermal cycling done. Takahashi and chai in another study achieved the highest bond strength of 5.6 MPa for kooliner by treating the surface of denture base with dichloromethane[57].

Various studies have investigated the effect of prebond surface treatment modalities such as mechanical abrasion, use of chemical agents, laser treatment, and UV light irradiation etc. on various properties of the liners. Mechanical means of surface treatments such as polishing with silicone carbide paper and air abrasion, theoretically improved the bond between denture reline and denture base resins by removing contaminants, providing mechanical retentive feature and offering a large surface area for retention.

Kulkarni et al[33] (2007) studied the effect of denture base surface pre-treatments on the bond strength of two long term resilient liners. They found out that chemical agents such as monomer application increased the bond strength whereas sandblasting resulted in a decrease of bond strength. The effect of roughening the surface of the denture base on the bond strength of the soft liner is not well established. Craig et al[13] advocated a roughened surface to improve the adhesive bond strength whereas Amin et al[6] reported that roughening the acrylic resin base by sandblasting before applying liner material had a weakening effect on the bond. Minami [41] also found that liners bonded to smooth surface had better bond when compared to those bonded to air abraded surface. He proposed that air abraded resin surfaces may have pits, cracks, crevices, discontinuities with sharp corners and projections. These surface irregularities may not allow complete flow of the soft denture liner and may result in the formation of small voids by air entrapment. Therefore, stress concentrations may be developed in the vicinity of the bonding interface and initiate failure during bond strength testing.

In the present study, surface pretreatment was done to simulate the clinical scenario of chair side relining by removal of a layer of acrylic resin by mechanical abrasion using silicone carbide paper followed by sand blasting. For the silicone liner groups (S1, S2) this was followed by application of primer liquid supplied by the manufacturer, since silicone based soft liners have little or no chemical adhesion to PMMA denture base resin. Thus the

bond strength of silicone based denture liners depend on the strength of the liner and the adhesiveness of primers used. Although the exact chemical composition of such proprietary primers is not known, it is speculated that they may consist of an organic solvent and adhesive monomer which react with both silicone and resin material[41].

Soft denture liners are expected to function in adverse oral environment for long periods of time as well as under rapidly changing temperatures. However, it must be noted that with cyclic temperatures, the thermal behaviour of the structural components within a material can influence the latter's mechanical and physical properties. In this connection, the thermocycling process can give useful data on the longevity of denture liners with respect to mechanical properties under conditions that simulate clinical usage. By means of thermocycling, cumulative effects of fatigue arising from sudden temperature changes can be determined. In the current study, soft denture liners were subjected to fatigue stress by virtue of temperature differences between water baths of thermocycler.

Intra-oral temperature changes may be induced by routine eating, drinking and breathing. Thermal stresses can be pathogenic in two ways. Firstly, mechanical stresses induced by thermal changes can directly induce crack propagation through bonded interfaces. Secondly, the change in gap dimensions is associated with gap module changes which pump pathogenic oral fluids in and out of the gaps. Also, thermocycling promotes the hydration

of specimens which further simulates the oral condition[20]. The absorbed water molecules, which act as a plasticizer may percolate directly at the bond interface and decrease the bond strength between the denture base and the relined resin. On the other hand, during thermocycling, the residual monomer which also acts as a plasticizer may be reduced by leaching into the water and further the polymerization reaction, thus increasing the bond strength of relined resin to denture base. Resin denture liners immersed in water leach out plasticizers and absorb water. This in addition to the rapidly changing temperatures during thermocycling affects the compliance and dimensional stability of the material. The material becomes brittle and external load is transferred to the interface.

In the present study, ten samples each of acrylic and silicone based liners (Groups A2,S2) were subjected to thermocycling for 250 cycles between 5˚c and 55˚c with a dwell time of 1 minute in an automated thermocycling unit. Also, the number of thermal cycles used in this study were less (250 cycles) since the materials used are short term resilient liners. Thermocycles simulating three months of clinical usage were employed. Botega et al[12] (2008) considers 1000 cycles between 5˚c and 55˚c with one minute dwell time as equivalent to 1 year of clinical service. Also Goiato et al[23] (2009) employed 2000 thermal cycles with similar temperatures and dwell time to simulate 2 years of complete denture use. This is in concurrence with the regimens employed by Torres Leon et al[35] (2005) and

Riperio Pinto et al[50](2004) in their studies. Neppelenbronek et al[45] assessed the shear bond strength of four hard chair side reline acrylic resins to PMMA and found out that their bond strength in general were comparable and not affected by thermo cycling.

The marginal decrease or increase in the shear bond strength of the materials tested after thermocycling in the present study has been shown to be not statistically significant. The paired 't' test yielded a two-tailed 'p' value of 0.106 for the acrylic control and thermocycled groups (A1, A2). The same for silicone control and thermocycled groups (S1, S2) was 0.161. The independent 't' test between the acrylic and silicone control groups (A1, S1) yielded a 'p'value < 0.0001. This difference is considered to be extremely statistically significant. The independent 't' test between the thermocycled groups of acrylic and silicone softliner (A2, S2) yielded a 'p' value < 0.0001. This difference is considered to be extremely statistically significant. The inference is that there is a significance difference in the shear bond strength values between the acrylic based liner and the silicone based liner. This is true even after the specimens were subjected to thermocycling.

Hence, the choice of a soft liner is based on the expected duration of service of the material in addition to a host of other factors. It can be concluded that both acrylic and silicone based soft liners can be used as temporary and interim resilient liners effectively for a period ranging from seven days to three months. To be used as a permanent liner, silicone based

liners are recommended since they have a better bonding to the denture base and are also known to retain their softness and viscoelastic properties for a longer period of time. The minimal water sorption, improved polymerization and biocompatibility favour the use of these materials for long term relining.

The shear bond strength testing was carried out by applying shear force parallel to the liner-acrylic resin interface by means of a knife edged chisel mounted on a universal testing machine at a crosshead speed of 5mm/minute. This resulted in the debonding of the liner from the acrylic resin. The mode of failure (debonding) can give valuable inputs regarding the mechanism of bonding. Qualitative analysis of the interface after testing was performed by using scanning electron microscopy to characterize the mode of failure. When observed under the scanning electron microscope, both the acrylic liner groups showed a predominantly adhesive mode of failure with only a few areas of liner remaining adhered to the acrylic resin. This is indicative of the weak adhesive bond which may be attributed to the poor monomer penetration and failure to form a strong interpenetrating network of polymers. Mixed failure mode was predominant in groups with higher shear bond strength. Silicone based liners under magnification showed mixed mode of failure. Areas of both the liner and resin were visible, but the area of liner was more than that which is seen in the acrylic based liner groups. The predominant mixed mode of failure in silicone liner groups can be attributed to the primer used. The outline of the primer can be seen as a distinct layer along the boundary of the bonding

area. This layer was intact even after thermocycling. Hence it can be safely inferred that the bonding of silicone based liner was definitely better than the acrylic based liner to the heat polymerized PMMA resin used in this study.

Kulak-Ozkan et al[32] observed adhesive, cohesive and mixed mode of failure of the liner-acrylic denture base bond in their study on six resilient silicone liners. Thermocycled specimens showed predominantly mixed and adhesive failure which is in line with the SEM results obtained in the present study. Thus, the SEM analysis findings were in corroboration with the quantitative shear bond strength values obtained in this study.

This study was conducted in vitro and laboratory tests do not necessarily represent the load that the lining material can withstand clinically because in laboratory tests only one type of force is applied at a time compared with the various masticatory forces that dentures are subjected to clinically. This factor in addition to the complex nature of the bonding phenomenon itself and the fact that the test specimens do not accurately simulate the denture configuration makes it difficult to interpret the significance of the laboratory bond strength test results. However these tests are useful when comparing and ranking the bond strength of different commercially available lining materials. The focus of this study was to evaluate the shear bond strength of soft liners mainly used for a short term such as during healing period of the denture bearing tissues. Therefore thermal setting period was relatively short compared to other studies. As the clinical

relevance of thermal setting varies depending on the protocols, equating thermocycling to actual clinical usage may not be accurate. Thus further clinical investigations are needed to evaluate the long term reliability of adhesive strength between relining materials (acrylic liners and silicone elastomers) and denture base materials. In addition, other properties such as staining, discolouration and irritation to oral tissues are also important for the clinical success of the relining technique and these needs to be investigated further by means of long term clinical trials.

CONCLUSION

The following conclusions were drawn from the data obtained from the present in vitro study conducted to comparatively evaluate the shear bond strength of two chair side soft liners to heat polymerized polymethyl methacrylate denture base resin before and after thermocycling and correlated with qualitative surface texture analysis using scanning electron microscopy.

1. The mean shear bond strength of autopolymerizing plasticized acrylic soft liner to heat polymerized denture base resin before thermocycling was found to be 0.3365 ±0.025 MPa (Group A1).
2. The mean shear bond strength of autopolymerizing plasticized acrylic soft liner to heat polymerized denture base resin after thermocycling was found to be 0.3164 ±0.04 MPa (Group A2).
3. The mean shear bond strength of silicone based soft liner to heat polymerized denture base resin before thermocycling was found to be 0.4159 ±0.025 MPa (Group S1).
4. The mean shear bond strength of silicone based soft liner to heat polymerized denture base resin after thermocycling was found to be 0.4335 ±0.02 MPa (Group S2).
5. On comparison of the mean shear bond strength of autopolymerizing plasticized acrylic soft liner to heat polymerized denture base resin before (Group A1 = 0.3365 ±0.025 MPa) and after (Group A2 = 0.3164 ±0.04 MPa) thermocycling, it was found that Group A2 showed

a lesser value. Since the p value (p value = 0.194) was greater than 0.05, the decrease in shear bond strength after thermocycling was not statistically significant.

6. On comparison of the mean shear bond strength of silicone based soft liner before (Group S1=0.4159 ±0.025 MPa) and after (Group S2 = 0.4335 ±0.02 MPa) thermocycling, it was found that Group S2 showed higher value. Since the p value (p value = 0.101) was greater than 0.05, the increase in shear bond strength after thermocycling was not statistically significant.
7. On comparison of the mean shear bond strength of auto polymerizing plasticized acrylic based soft liner (Group A1 = 0.3365 ±0.025 MPa) and silicone based soft liner (Group S1 = 0.4159 ±0.025 MPa) before thermocycling, it was found that Group S1 showed higher shear bond strength. Since the p value (p value = 0.0001) was less than 0.05 the difference was statistically significant.
8. On comparison of the mean shear bond strength of auto polymerizing plasticized acrylic based soft line (Group A2 = 0.3164 ±0.04 MPa) and silicone based soft liner (Group S2 = 0.4335 ±0.02 MPa) after thermocycling, it was found that Group S2 showed higher shear bond strength. Since the p value (p value = 0.0001) was less than 0.05 the difference was statistically significant.
9. On overall comparison of the mean shear bond strengths of auto polymerizing plasticized acrylic based soft liner and silicone based soft

liner before and after thermocycling, (Group A1, Group A2, GroupS1 and Group S2), silicone based soft liner showed higher shear bond strength than acrylic based soft liner both before and after thermocycling. Shear bond strength reduced for acrylic based soft liner while it increased for silicone based soft liner after thermocycling.

10. The qualitative evaluation of the mode of failure of the tested samples using scanning electron microscopy under 14x, 50x and 150x magnifications revealed the following:
    a. Acrylic based soft liner exhibited predominantly adhesive failure pattern at the liner-acrylic resin interface as observed on the surface of the acrylic resin block, before thermocycling (Group A1).
    b. Acrylic based soft liner exhibited predominantly adhesive failure pattern at the liner-acrylic resin interface as observed on the surface of the acrylic resin block, after thermocycling (Group A2).
    c. Silicone based soft liner exhibited a mixed adhesive and cohesive failure pattern at the liner-acrylic resin interface as observed on the surface of the acrylic resin block, before thermocycling (Group S1).
    d. Silicone based soft liner exhibited a mixed adhesive and cohesive failure pattern at the liner-acrylic resin interface as

observed on the surface of the acrylic resin block, after thermocycling (Group S2).

SEM observation revealed that the mixed failure mode was predominant in groups with higher shear bond strength (Group S1 and GroupS2), while adhesive failure mode was predominant in groups with lower shear bond strength (Group A1 and Group A2). This qualitative assessment of the present study is in correlation with the quantitative results obtained.

SUMMARY

The present study was conducted in vitro to comparatively evaluate the shear bond strength of two chair side, soft relining materials namely autopolymerizing plasticized acrylic resin and silicone based liner bonded to heat polymerized Poly methyl methacrylate denture base resin before and after thermocycling and to characterize the mode of interfacial bond failure using scanning electron microscopy.

A total of forty (n =40) heat polymerized acrylic denture base resin blocks were fabricated from a custom made stainless steel mold. The surface of the acrylic resin blocks on which the resilient liners would be bonded were abraded with a silicon carbide paper and then air abraded with aluminium oxide particles. A cylindrical column of soft liner, was bonded to a circular area onto the abraded surface of heat polymerized acrylic denture base resin blocks. Acrylic based soft liner was bonded to 20 randomly selected acrylic blocks (Group A1, n= 10 & Group A2, n =10) and silicone based soft liner was bonded to the remaining 20 acrylic blocks (Group S1, n=10 & Group S2, n=10) after application of the primer liquid supplied by the manufacturer. Ten samples each of acrylic (Group A2) and silicone based (Group S2) soft liners were subjected to thermocycling in an automated thermocycler to simulate a clinical usage of three months.

All the forty samples were subjected to shear bond strength testing in an universal testing machine. One representative sample from each group was then subjected to surface analysis using scanning electron microscopy. The data obtained were tabulated and statistically analysed. The mean shear bond strength values obtained for acrylic based soft liner before (Group A1) and after (Group A2) thermocycling were 0.3365 ±0.025 MPa and 0.3164 ±0.04 MPa respectively. The mean shear bond strength values obtained for silicone based soft liner before (Group S1) and after (Group S2) thermocycling were 0.4159 ±0.025 MPa and 0.4335 ±0.02 MPa respectively.

It was concluded in the present study that silicone based soft liner exhibited higher shear bond strength values to the heat polymerized acrylic denture base resin than the acrylic based soft liners before and after thermocycling of samples. SEM observation revealed that the mixed failure mode was predominant in groups with higher shear bond strength (Group S1 and GroupS2), while adhesive failure mode was predominant in groups with lower shear bond strength (Group A1 and Group A2). This qualitative assessment of the present study is in correlation with the quantitative results obtained.

The marginal increase in shear bond strength with silicone based soft liner and the marginal decrease of the same with the acrylic based soft liner after thermocycling was found to be statistically insignificant in this study. The results of the present study revealed that the Silicone based soft liners are

preferable than the acrylic based liners for the chair side relining procedure. The selection of soft denture liner cannot be based on any single property in clinical practice. In addition to bond strength, other properties such as staining, discoloration and irritation to oral tissues are also important for the clinical success of the relining technique and these needs to be investigated further by means of long term clinical trials.

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